The Economic Impact of Broadband Investment

by

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In this paper we analyze the economic impact of broadband deployment on consumer welfare, job creation, and economic output. This study represents an update of prior studies conducted in 2001 and in 2003, in which we made several projections based on the best available data at the time. We begin by comparing those predictions against the actual U.S. broadband experience during the past decade. As it turns out, many of our predictions concerning economic welfare and employment/output effects were conservative because we could not envision the myriad applications made possible by broadband connections; nor could we envision the rate at which broadband access prices would fall. In a largely deregulatory climate, broadband penetration skyrocketed to nearly 65 percent penetration by the end of the decade as absolute and quality-adjusted prices fell, and first-generation technologies—cable modem, DSL, and 3G wireless—individually covered approximately 90 percent of all U.S. households and collectively covered even more. In the second part of the paper, we analyze how much additional investment will naturally occur to wire the country with next-generation technologies. That new investment will expand domestic output and it will create new jobs. We also estimate the output and job effects under an alternative scenario in which next-generation deployment is accelerated and is expanded in scope. Recognizing our limited ability to conceptualize next-generation applications, we attempt to estimate the spillover effect of next-generation technologies on other sectors of the economy. Finally, we briefly assess various policy options facing regulators. Given the amount of investment that continues to be deployed in this sector and the precarious current state of the U.S. economy, and given the linkage between that investment and jobs/output, regulators must diligently avoid taking any steps that might undermine the industry's incentives to invest.

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I. INTRODUCTION AND EXECUTIVE SUMMARY

Investments in information and communications technology have contributed massively to the growth in the U.S. economy and, as a result, to consumer welfare over the last two decades. When the economy is expanding, policymakers should be concerned about improvements in productivity and increases consumer welfare in both the short and long term. When the economy is contracting, as it did in 2008 and in the beginning of 2009, policymakers should also be concerned about stimulating demand and creating jobs. There is perhaps no better way to create jobs than to stimulate investment. Given the massive investment that has been made to wire the U.S. economy with first-generation broadband access technologies, and given the significant investment now planned by carriers to upgrade that infrastructure to second-generation access technologies, policymakers must be careful to avoid new regulations that would make such investments unattractive.

Although economies of scale inherent in communications markets will necessarily limit the number of facilities-based broadband service providers ("BSPs"), the *performance* of the broadband service industry suggests that competition is very intense. The prices for broadband services have declined rapidly over the past decade,[3] and the percentage of homes with a broadband connection has expanded greatly—by the end of 2009, nearly 65

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3. *See, e.g.,* Comments of Robert W. Hahn, NBP Public Notice # 13, Nov. 19, 2009 (showing that the price of Verizon's lowest-speed DSL offering declined by 81 percent from 2001 to 2008); International Telecommunications Union, Measuring the Information Society: The ICT Development Index, 2009, at 65-66, *available at* http://www.itu.int/ITU-D/ict/publications/idi/2009/material/IDI2009_w5.pdf (finding that the United States is the most affordable on a currency-exchange-rate basis, and fourth most affordable on a PPP basis); OECD, Broadband Growth and Policies in OECD Countries (2008), Figure 1.14 (finding that the low end of U.S. broadband prices in 2007 ranked *fifth* in a 30-country survey of prices); Pew Internet, Home Broadband Adoption 2009, at 25 (finding that average U.S. broadband prices fell by four percent between December 2005 and April 2008, even as speeds increased) [hereinafter *Pew Report*].

percent of all U.S. households subscribed to broadband.[4] A decline in absolute prices matched by an increase in output means that annual consumer welfare—measured as the difference between a consumer's willingness to pay for broadband less the access price, summed over all consumers—associated with broadband consumption has increased significantly over the past decade. The most likely cause of the higher output was a shifting out of the demand curve for broadband services, which is precisely what we predicted in our earlier reports on the broadband industry.

In this report we briefly take stock in the investment in first-generation access technologies that occurred since we last predicted the benefits of broadband in 2003. First-generation access technologies came primarily in three flavors: cable modem, DSL, and 3G wireless. The investments and the associated job creation relative to a world without such investments were impressive:

- Annualized investment in ***cable modem*** from 2003 to 2009 was $4.3 billion, which corresponds to 63,400 jobs created.
- Annualized investment in ***DSL* and fiber** from 2003 to 2009 was $11.7 billion, which corresponds to 202,400 jobs created.
- Annualized investment in ***3G wireless and satellite technologies*** from 2003 to 2009 was $11.6 billion, which corresponds to 168,300 jobs created.

Across the three technologies, the cumulative jobs effect associated with that investment over the past decade was 434,100 (equal to 63,400 plus 202,400 plus 168,300). Investment in first-generation access technologies resulted in 92 percent of U.S. homes having access to cable modem service;[5] 82 percent of U.S. homes having access to DSL;[6] and 92 percent of

4. *Pew Report*, *supra*, at 3 (finding increases in broadband penetration from 47 percent in 2007 to 63 percent by 2009). Quality-adjusted prices have declined even more rapidly, inducing many consumers to upgrade to a similarly-priced new plan with faster download speed.
5. SNL Kagan (2008), *available at* http://www.ncta.com/Statistics.aspx (accessed on Nov. 12, 2009).

the population having access to a wireless 3G network in their primary place of residence.[7] Such ubiquitous coverage implies that most U.S. households have a choice of at least three broadband technologies and of even more suppliers (as there are generally *multiple* nationwide 3G wireless suppliers operating in the same local service area).

As impressive as that investment was, even greater investments are now being made. U.S. BSPs are upgrading their existing infrastructure with next-generation access technologies. The major varieties of next-generation broadband technology include fiber-to-the-home (FTTH), fiber-to-the-node (FTTN), DOCSIS 3.0, and 4G wireless. To reach the same coverage levels as they achieved with first-generation technologies, we estimate that that the annual average investment by BSPs over the next six years (2010-15) will be:

- $12.5 billion in wireline broadband, including ***FTTH and FTTN***, which corresponds to 247,000 jobs created.
- 3.6 billion in cable broadband, including ***DOCSIS 3.0***, which corresponds to 52,000 jobs created.
- $14.0 billion in ***wireless technologies***, which corresponds to 205,000 jobs created.
- $300 million in ***satellite broadband***, which corresponds to over 4,000 jobs created.
- $30.4 billion in ***all broadband technologies***, which corresponds to over 509,000 jobs created.[8]

Much of the investment in next-generation technologies is already underway. For example, Verizon has invested nearly $23 billion in establishing its FTTH network, known as FiOS,

6. Federal Communications Commission, In the Matter of Inquiry Concerning the Deployment of Advanced Telecommunications Capability to All Americans in a Reasonable and Timely Fashion, and Possible Steps to Accelerate Such Deployment Pursuant to Section 706 of the Telecommunications Act of 1996, Fifth Report (June 12, 2008), Appendix B, Table 14.

7. Comments of CTIA-The Wireless Association, WC Dkt. No. 05-337, filed April 17, 2008, at Attachment 1 (finding that 92 percent of the population has access to a wireless 3G network in their primary place of residence).

8. Once again, the job creation associated with this investment is relative to world without such investments.

since 2004.[9] AT&T spent nearly $5 billion on its U-Verse network from 2006 through 2008.[10] In 2009, Comcast invested between $400 and $500 million in upgrading its network to DOCSIS 3.0.[11] It is no accident that while private, non-residential investment in all U.S. industries was shrinking at an annual rate of more than 20 percent between the third quarter of 2008 and the third quarter of 2009,[12] investment in the broadband industry held its ground in the current recession. Nonresidential private investment declined by 18.1 percent in nominal terms from 2008 to 2009 (from $1.693 trillion to $1.386 trillion),[13] while broadband investment declined by only 3.3 percent in nominal terms (from $31.04 billion to $30.01 billion).

Not all of the news relating to broadband is good, however. Across the communications and utility-related construction industries, more than 123,000 jobs were lost over the two-year period between the beginning of the recession in December 2007 and the end of 2009.[14] Significant investment is needed to restore those lost jobs. We estimate that the going-forward capital expenditures in next-generation access technologies would create approximately 509,000 jobs relative to a world without such investments *so long as no new regulatory changes undermine the incentives of BSPs to continue to invest.* Indeed, it is not an overstatement to say that the planned investment of

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9. Saul Hansen, *Verizon's FiOS, A Smart Bet or a Big Mistake*, N.Y. TIMES, August 18, 2008.
10. *See* Appendix, Table A-3.
11. Comcast Corporation Earnings Conference Call (Q42008), at 7, *available at* http://files.shareholder.com/downloads/CMCSA/0x0x299976/9e745136-9e7a-472e-8a25-e6f4131b20c7/CMCSA-Transcript-2009-02-18.pdf (accessed on Dec. 23, 2009).
12. BUREAU OF ECONOMIC ANALYSIS, NATIONAL ACCOUNTS, Nonresidential fixed investment, *available at* http://bea.gov/national/nipaweb/SelectTable.asp?Selected=Y (Table 5.3.1).
13. *Id.* at Table 1.1.5.
14. U.S. Department of Labor, Bureau of Labor Statistics, Employment, Hours, and Earnings from the Current Employment Statistics Survey, *at* http://www.bls.gov/ces/cesprog.htm (last visited Jan. 8, 2010).

U.S. BSPs is critical to the larger U.S. economic recovery.

Unfortunately, some policymakers have threatened to change the regulatory landscape substantially. At the urging of lawmakers, the Federal Communications Commission (FCC) has initiated several broadband-related proceedings, including a requirement to develop the federal government's first national broadband plan. Given broadband's critical importance to the U.S. economy, crafting a forward-looking plan that focuses on those geographic areas where broadband has not yet reached or those population segments that have not adopted broadband is a worthwhile public endeavor. However, it is important that this and other related inquiries do not result in new restrictions for BSPs that would reduce innovation at the "core" of the network.

To correct the private market's perceived "failure" to make broadband available to 100 percent of U.S. homes, some are suggesting re-imposing mandatory unbundling rules on incumbent carriers, while others have proposed providing subsidies or grants only to those BSPs that would agree to deploy under-served areas with a wholesale-only model. Both of these policy options would be a serious mistake because they would inhibit investment.

Another regulatory threat concerns a BSP's ability to utilize new network capabilities in a manner that provides quality-sensitive applications differentiated handling and charges a price for such prioritization in contracts between BSPs and content providers. According to the Commission's recent *Notice of Proposed Rule Making* on net neutrality, the privately optimal fee for such service is (surprisingly) zero, as the private benefits to BSPs from encouraging entry among content providers is allegedly greater than the forgone revenues from such surcharges. But competition among BSPs might cause each BSP to choose a positive price for prioritization, which would unravel the Commission's idealized equilibrium. To correct this perceived market failure, proponents of net neutrality seek to impose, among other things,[15] a zero-pricing rule for prioritization. In this report, we explain why each of those proposals mentioned here would undermine the incentives of BSPs to invest in next-generation access technologies. We also provide concrete policy proposals that would *bolster* the investment incentives faced by BSPs, which would create more jobs, more economic growth, and more consumer welfare.

The net neutrality proposals currently being contemplated by the Commission mistakenly imply that the most important source of future innovation is at the "edge of the network"—that is, proponents believe that investments by content providers are somehow more valuable than investments by BSPs. Although investment at the edge of the network is certainly important, there is a clear track record of job and wealth creation associated with investment in first- and second-generation access technologies, suggesting that investment at the core of the network is equally if not more important. Accordingly, policymakers should take efforts to promote *both* investments at the core of the network and at the edge of the network.

15. The net neutrality proposals would also seek to freeze the currently prevailing business models in place, which would prevent BSPs from differentiating their services.

II. Our Earlier Studies

We begin by briefly reviewing our previous estimations on the benefits of broadband in 2001[16] and 2003.[17] In both of these studies, we estimated the consumer surplus derived from broadband Internet adoption, and the consumer benefits from universal broadband deployment. The later work, however, also considered investment in both first- and second-generation technologies, and made forecasts of how this investment would affect economic output and employment. In both cases, we could not have foreseen the vast technological improvements that have developed over the past decade. Table 1 below summarizes the results of these two studies.

16. Robert W. Crandall & Charles L. Jackson, The $500 Billion Opportunity: The Potential Economic Benefit of Widespread Diffusion of Broadband Internet Access, July 2001 [hereinafter *$500 Billion Opportunity].*

17. Robert W. Crandall, Charles L. Jackson, & Hal J. Singer, *The Effect of Ubiquitous Broadband Adoption on Investment, Jobs, and the U.S. Economy*, New Millennium Research Council Sept. 2003 [hereinafter *Ubiquitous Broadband Adoption*].

TABLE 1: SUMMARY OF PREVIOUS ESTIMATES OF THE BENEFITS FROM UNIVERSAL BROADBAND ADOPTION ($ BILLIONS, EMPLOYMENT IN NUMBER OF JOBS)

	2001 Estimates	2003 Estimates
ANNUAL CONSUMER SURPLUS ESTIMATES UNDER LINEAR DEMAND*		
At Actual Penetration Levels at Time of Study	$1.4 to $2.0	$6.3 to $9.5
At 50% Penetration	$80 to $121	$64.4 to $96.6
At Ubiquitous Level	$284 to $427	$234 to $351
ANNUAL CONSUMER SURPLUS ESTIMATES UNDER LOG LINEAR DEMAND*		
At Actual Penetration Levels at Time of Study	N/A	$6.5 to $8.4
At 50% Penetration	N/A	$17.0 to $37.7
At Ubiquitous Level	N/A	$32.3 to $71.9
ANNUAL CONSUMER BENEFITS FROM UNIVERSAL BROADBAND DEPLOYMENT		
DIRECT ESTIMATES FROM DEMAND CURVE		
Broadband Access Subscription	$284 to $427	$234 to $351
Household Computer & Network Equipment	$13 to $33	$20
Total Benefits	$297 to $460	$254 to $371
ALTERNATIVE ESTIMATE BASED ON SUBSTITUTION		
Shopping	$74 to $257	$78 to $270
Entertainment	$77 to $142	$77 to $142
Commuting	$30	$15
Telephone Services	$51	$44
Telemedicine	$40	$20 to $40
Total Benefits	$272 to $520	$234 to $511
CAPITAL EXPENDITURES, 2003-2021		
First Generation Broadband	N/A	$63.6
Second Generation Broadband	N/A	$93.4
First and Second Generation Broadband	N/A	$146.43
ANNUAL EMPLOYMENT, 2003-2021		
From First Generation Investment	N/A	60,656
From First and Second Generation Investment	N/A	140,000
CUMULATIVE ECONOMIC OUTPUT (GDP), 2003-2021		
From First Generation Investment	N/A	$179.7
From First and Second Generation Investment	N/A	$414.0

Notes: * Our definition of ubiquitous broadband adoption in 2001 was 94 percent, but in 2003 was 95.3 percent. The estimates were calculated under a range of elasticities of -1.5 to -1. The estimates under a log linear demand curve are calculated under the assumption of a choke price of $120.

In 2001, we undertook a study of the benefits that broadband Internet access would bring to U.S. consumers and to the economy. We used two approaches to assess the eventual economic benefits of broadband. *First*, we modeled the demand for high-speed access once broadband had time to diffuse throughout the country, which we estimated would take 15 to 25 years. From this demand function we calculated the consumer surplus associated with high-speed access priced at $40 per month. We also estimated the benefits to consumers from non-broadband use of the higher-quality network and computing equipment that would be used with their high-speed network access. *Second,* we examined the benefits that high-speed access would eventually provide, and calculated the consumer surplus associated with each benefit. This approach provided a check of our first set of estimates. Using these two approaches, we concluded that the eventual consumer benefit of universal broadband could be as much as $100 to $300 billion per year. We estimated that the benefit for producers of electronic equipment used in the delivery of broadband services, household computer and networking equipment, and household entertainment could be between $50 and $100 billion per year. Combining these two estimates, we projected that the net present value of broadband services could be between $140 and $500 billion per year.

In 2003, we estimated the impact of universal residential broadband adoption on consumers, investment, employment, and economic output. Much like our 2001 work, we began by estimating the consumer surplus of universal broadband adoption. Then we forecasted residential broadband adoption and capital spending through 2021 using analyst reports. Finally, using BEA input-output multipliers, we projected the potential impact of capital spending on national employment and gross domestic product (GDP). We calculated these impacts for both first- and second-generation technologies. Before accounting for second-generation adoption, we found that ubiquitous broadband adoption would result in $64 billion in capital expenditures by DSL and cable operators through

2021. We projected that this investment would be associated with a cumulative increase of $180 billion in GDP, and account for 61,000 additional jobs per year. We found that investment in second-generation technologies, such as fiber-to-the-home (FTTH) and very high-speed digital subscriber lines (VDSL), over the same time horizon would be $93 billion. Because adoption of more advanced access technologies comes at the expense of current generation subscriptions, the two effects are not completely additive. We found that investments in more advanced access technologies would displace $10.6 billion of investment in current generation technologies. Thus, we estimated that the combined investment in first- and second-generation technologies would be $146 billion, creating 140,000 new jobs per year. We concluded that if residential broadband became ubiquitous, and if the effects of increased consumer spending on capital investment in other industries were considered, then more than 1.2 million jobs could be created as a result of ubiquitous residential broadband adoption. The following section analyzes how our 2003 projections compare to the empirical evidence.

III. ACCURACY OF PAST PREDICTIONS

The purpose of this section is to assess the accuracy of our 2003 predictions. Table 2 compares our predictions to the actual results that have occurred in the past seven years. The following is a brief "report card" assessing the precision of our predictions:

- We estimated residential broadband penetration fairly accurately,[18] with the rate approaching or exceeding 60 percent in 2009 depending on the source.[19]

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18. For our original projections *see Ubiquitous Broadband Adoption, supra,* Table 3 at 11.

19. We compare our estimates to figures reported by Pew Internet, the Federal Communications Commission (FCC), and Morgan Stanley. *See* Pew Internet Broadband Adoption Surveys 2005-2009; Federal Communication Commission, High Speed Services for Internet Access (June 2008); U.S. Census Bureau (number of households); Crandall, Jackson, & Singer figures come from *Ubiquitous Broadband Adoption* Table

- We appear to have under-estimated investment in first- and second-generation residential broadband technologies.[20] Making an apples-to-apples comparison between our projections and the actual experience is challenging because: (1) providers do not report broadband investments separately from broader categories of investments; (2) estimates of broadband investments generally do not provide separate estimates for business and residential investment; and (3) at the time of our predictions, we did not consider the development of first-generation wireless technologies.
- We accurately predicted consumer expenditures on computer equipment, peripherals, and software from 2003 to 2007.[21] Expenditures from 2007 to 2009 did not meet our projections—an unsurprising result given the recession that began in 2007.
- We likely underestimated the multiplicative effect of broadband investment on jobs and economic output.[22] Any retrospective analysis of this effect is necessarily imperfect; therefore, we cannot know with certainty the accuracy of our original assessment.
- Our forward-looking estimates of consumer surplus that would ultimately be enjoyed by U.S. consumers was reasonable based on a comparison of our elasticity assumptions with more recent estimates of the price elasticity of broadband demand.[23]
- As we predicted, broadband has provided tremendous value to consumers in shopping, entertainment, commuting, telephony, telemedicine, social networking, education, electricity, and transportation.[24]

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3 at 11 . Morgan Stanley, Broadband Outlook: Cable Modem Speeds Boosting Market Share, Morgan Stanley Research (2008) Exhibit 30 at 19.

20. For our original projections *see Ubiquitous Broadband Adoption*, *supra*, Table 8 at 20; We compare 2003 our investment forecasts to capital expenditures reported by the Columbia Institute of Tele-Information (CITI), and the U.S. Census Bureau's Annual Capital Expenditure Survey (ACES). *See* Robert C. Atkinson & Ivy E. Schultz, Columbia Institute for Tele-Information (CITI), *Broadband in America: Where It Is and Where It Is Going (According to Broadband Service Providers)*, Preliminary Report Prepared for the Staff of the FCC's Omnibus Broadband Initiative, Nov. 11, 2009, at Table 15 [hereinafter *Broadband in America*]; U.S. Census Bureau, 2007 Annual Capital Expenditure Survey, Table 4a, and 2004-2006 Annual Capital Expenditure Survey, Table 4b, *available at* http://www.census.gov/csd/ace/ (accessed on Jan. 10, 2010).

21. For our original projections of consumer expenditures on computer, peripherals, and software, *see Ubiquitous Broadband Adoption*, *supra*, at 7-9; We compare these estimates to the latest available data from the BEA, *see* Bureau of Economic Analysis (BEA), Table 2.4.5U Personal Consumption Expenditures by Type of Product, data downloaded at http://www.bea.gov/national/nipaweb/nipa_underlying/Index.asp (accessed on Dec. 23, 2009).

22. There is no straight-forward method to test the accuracy of our predictions. The next best alternative is to compare the multipliers an investment used in our previous analysis to more recent estimates. For our original multipliers, see *Ubiquitous Broadband Adoption*, *supra*, at 14-16; We compare our multipliers with the weighted average multipliers calculated by Eisenach, Singer, and West. *See* Jeffrey A. Eisenach, Hal J. Singer, & Jeffrey D. West, *Economic Effects of Tax Incentives for Broadband Infrastructure Deployment*, Fiber-to-the-Home Council (2008) at 8.

23. It is difficult to measure consumer surplus directly ex-post. The next best alternative is to compare our estimates of elasticity to the latest reported measures of elasticity. Our elasticity estimates (-1 to -1.5) are in line with those calculated by Dutz, Orzag, and Willig (-0.69 to -1.53). For our previous projection of consumer surplus, *see Ubiquitous Broadband Adoption*, *supra*, at 6-7; for the Dutz, Orzag, Willig estimates, *see* Mark Dutz, Jonathan Orszag, & Robert Willig, *The Substantial Consumer Benefits Of Broadband Connectivity For U.S. Households*, Internet Innovation Alliance, July 2009, at 7.

24. For our projections, see, *Ubiquitous Broadband Adoption*, *supra*, at 9; For a detailed description of recent developments in broadband applications see Section II-H below.

➢ A 2007 study by Crandall, Lehr, and Litan corroborates our claim that broadband would have spill-over effects in other sectors of the economy.[25]

TABLE 2: 2003 PREDICTIONS VS. ACTUAL RESULTS

PREDICTED VS. ACTUAL	2003	2004	2005	2006	2007	2008	2009
PENETRATION RATES							
2003 Forecast	20%	26%	32%	37%	47%	53%	60%
Average Penetration Rates Reported by Analysts	17%	25%	34%	43%	51%	58%	59%
INVESTMENT IN FIRST AND SECOND GENERATION DEPLOYMENT ($ BILLIONS)							
2003 Forecast	$5.1	$6.7	$7.1	$7.4	$8.6	$10.0	$8.2
Current Estimates	$18.2	$21.2	$27.9	$32.0	$33.3	$31.0	$30.0
BENEFITS OF HOUSEHOLD COMPUTING CAPACITY (CONSUMER EXPENDITURES ON COMPUTER EQUIPMENT) ($ BILLIONS)							
2003 Forecast	$42.9	$49.0	$56.0	$63.9	$73.0	$83.4	$95.2
Actual Expenditures	$45.1	$49.9	$54.3	$58.6	$63.6	$64.5	N/A
JOBS CREATED FROM BROADBAND INVESTMENT (THOUSANDS)							
2003 Forecast	93	121	129	134	155	181	149
Current Estimates	282	329	431	500	526	495	475
ECONOMIC OUTPUT FROM BROADBAND INVESTMENT ($ BILLIONS)							
2003 Projections	$14.5	$18.8	$20.0	$20.8	$24.2	$28.2	$23.2
Current Estimates	$52.6	$61.3	$80.6	$92.6	$96.8	$90.3	$87.2
CONSUMER WELFARE (COMPARISON OF ELASTICITIES USED)							
2003 Forecast				-1.5 to -1			
Dutz, Orzag, & Willig (2009)			-1.53	-1.17	-0.88	-0.69	

BENEFITS OF BROADBAND APPLICATIONS

Broadband has exhibited benefits in telemedicine, telecommuting, shopping, entertainment, electricity, transportation, VoIP, education, and social networking.

SPILLOVER EFFECTS IN OTHER INDUSTRIES

We predicted that broadband adoption would cause consumers to spend more in upstream industries, leading to increased capital spending by these upstream industries, which would create jobs, and economic output.

The remainder of this section discusses the developments in broadband since our 2003 report, and provides further detail on the assessment of our predictions.

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25. For our previous projections, see, *Ubiquitous Broadband Adoption*, *supra*, at 21-22. For the Crandall, Lehr, and Litan paper, *see*, Robert Crandall, William Lehr, and Robert Litan, *The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data*, THE BROOKINGS INSTITUTION: ISSUES IN ECONOMIC POLICY NO. 6 (2007).

A. Actual versus predicted broadband penetration levels

In our 2003 estimation of residential broadband penetration, we predicted that 95 percent of U.S. households would subscribe to broadband services by the year 2021.[26] As it turns out, the first seven years of our projections compare favorably to the actual penetration levels. Our original 2003 projections were based on Morgan Stanley's 2003 forecast of residential broadband adoption. We fitted an S-curve to Morgan Stanley's adoption rate between 1999 and 2006, and then used the regression coefficients to forecast the adoption rate for 2007 and later.[27] Table 3 compares our original projections from 2003 to the current estimates of residential broadband penetration provided by the FCC, Pew Research Center's Internet & American Life Project ("Pew Internet"), and Morgan Stanley's 2008 adoption forecast.[28]

26. *Ubiquitous Broadband Adoption, supra*, at 10.
27. *Id.* at 19-20.
28. As Table 1 shows, our 2003 projections never differ from the actual results by more than five percent. Indeed, beginning in 2006, our projections are always *less* than the actual penetration levels, suggesting that broadband adoption has occurred at a rate that is slightly faster than we originally predicted. We projected that broadband penetration would not reach 60 percent until 2010. Pew Internet's data, however, shows that the 60-percent-penetration threshold was reached in 2009, the FCC's data shows that the 60-percent-penetration threshold was broken in 2008, and Morgan Stanley does not project the 60 percent threshold to be broken until 2011.

TABLE 3: RESIDENTIAL BROADBAND PENETRATION

YEAR	CRANDALL, JACKSON & SINGER (2003) ESTIMATES	PEW INTERNET	FCC	MORGAN STANLEY
2003	20%	15%	17%	
2004	26%	24%	25%	
2005	32%	33%	31%	34%
2006	37%	42%	40%	42%
2007	47%	47%	51%	48%
2008	53%	55%	62%	52%
2009	60%	63%		55%

Sources: Pew Internet Broadband Adoption Surveys 2005-2009; Federal Communication Commission, High Speed Services for Internet Access (June 2008); U.S. Census Bureau (number of households); Crandall, Jackson, & Singer figures come from *Ubiquitous Broadband Adoption*, *supra*, Table 3 at 11. Morgan Stanley, Broadband Outlook: Cable Modem Speeds Boosting Market Share, Morgan Stanley Research (2008) Exhibit 30 at 19.
Notes: According to Pew Internet, the broadband adoption figure of 55% in its 2008 report came from "a sample of respondents that did not include individuals interviewed on cell phone, unlike the 2009 sample. The difference in sampling may have an impact on a 2008-2009 comparison, since those reached on cell phones may have systematically different broadband adoption habits than those reached on landline phones. Analysis of the effect of including cell respondents in the April 2009 survey indicates that this may increase the figure for home broadband adoption by 2 percentage points. In other words, absent cell phone respondents in the sample, 61% of Americans would be found to have broadband at home." John Horrigan, Home Broadband Adoption 2009, Pew Internet & American Life Project (2009), at 11; Morgan Stanley's 2008 and 2009 figures are estimations.

Based on the accuracy of our projections and the trends in demographics presented by Pew Internet, there is reason to expect that our prediction of broadband penetration reaching ubiquity (95.3 percent residential penetration) in 2021 will be met. Pew Internet's latest research shows that broadband adoption is growing fastest in previously under-represented groups.[29] For example, broadband usage for senior citizens (65 and older) grew 11 percent from 2008 to 2009.[30] Respondents with household incomes of $30,000 or less saw a growth in usage of 34 percent over the same period.[31] Additionally, usage in rural areas grew from 38 percent in 2008 to nearly 46 percent in 2009.[32] Such

29. John Horrigan, *Home Broadband Adoption 2009*, Pew Internet &American Life Project (2009), at 3 [hereinafter *Home Broadband Adoption 2009*].
30. *Id.*
31. *Id.*
32 . *Id.*

rapid growth in demographic groups with low broadband penetration in the past bodes well for increased residential penetration over time.

B. Actual versus predicted investment to support first and second generation deployment

In our 2003 paper, we predicted investment in both first- and second-generation deployment to be $146 billion from 2003-2021, with $53 billion invested from 2003 to 2009.[33] Recent reports seem to indicate that we under-estimated investment in the deployment of these technologies.

To aggregate investment over the past decade, we use estimates of capital expenditures reported by the Columbia Institute of Tele-Information (CITI) and the U.S. Census Bureau's Annual Capital Expenditure Survey (ACES). CITI reports U.S. carriers' total capital expenditures and broadband-specific capital expenditures beginning in 2008. ACES reports U.S. carriers' total capital expenditures only, which include non-broadband expenditures. Neither of the two sources reports separate estimates of residential and business broadband investment. Table 4 shows the estimates of total capital expenditures from each source.

33. Cable modem and DSL broadband require three types of capital investments: (1) deployment expenditures, or upgrading networks, (2) expenditures on customers' premises equipment (CPE), such as modems, and (3) maintenance capital expenditures. We predicted that between 2003 and 2021, cumulative investment in first generation residential broadband deployment would be $63.6 billion, or $3.35 billion per year, an average annual expenditure of just $0.97 billion by ILECs on DSL, and an average of $2.38 billion per year by cable operators on cable modems. We estimated that more advanced access technologies could pass 78.5 percent of U.S. households in 2021. Further, we predicted that the cumulative investment in more advanced access technologies would be $93.4 billion between 2003 and 2021, for an average of $4.9 billion per year. Through 2009, we projected a cumulative investment of $16.7 billion in these advanced technologies. Investment in advanced technologies will displace $10.6 billion in first generation investment. Thus net investment in first and second generation technology will be $63.6+$93.4-$10.6=$146.4. *See Id.* at 16-21.

TABLE 4: TOTAL COMMUNICATIONS CARRIER CAPITAL EXPENDITURES, 2003-2009
($ BILLIONS)

	2003	2004	2005	2006	2007	2008	2009
U.S. CENSUS ANNUAL CAPITAL EXPENDITURE SURVEY (ACES) ESTIMATES							
Wireline	$25.7	$24.5	$27.3	$32.1	$35.2		
Wireless	$21.0	$24.0	$27.3	$28.0	$22.2		
Satellite, Resellers, & Other Telecom	$3.8	$2.7	$3.2	$2.9	$3.4		
Cable	$10.0	$11.5	$12.9	$16.9	$18.6		
Total Capital Expenditures	***$60.5***	***$62.7***	***$70.8***	***$79.9***	***$79.4***		
CITI REPORT ESTIMATES							
Telco						$32.3	$25.9
Cable						$16.0	$14.3
Wireless						$20.7	$19.7
Satellite						$0.2	$0.2
WISP						$0.2	$0.2
Total Capital Expenditures						***$69.3***	***$60.4***

Source: *Broadband in America*, *supra,* Table 15; U.S. Census Bureau, 2007 Annual Capital Expenditure Survey, Table 4a, and 2004-2006 Annual Capital Expenditure Survey, Table 4b, *available at* http://www.census.gov/csd/ace/ (accessed on Jan. 10, 2010).

To estimate broadband capital expenditures from these aggregate estimates, we begin with CITI's estimate of broadband's share of total carrier investment for 2008 and 2009. Based on this analysis and other evidence, we then estimate broadband's share of carrier capital expenditures for 2003 to 2007.[34] CITI estimates that broadband accounted for 30 percent of total cable capital expenditures in both 2008 and 2009. Because cable systems were realizing strong growth in broadband subscriptions from 2003 to 2007, we assume that they devoted this same 30 percent of total capital expenditures to broadband annually from 2003 to 2007. CITI estimates that broadband's share of telecom companies' wireline capital expenditures increased from 48 percent in 2008 to 52 percent in 2009. Some of this increase was due to the growing importance of second-generation broadband, such as Verizon's FiOS. However, the telecom carriers' wireline expenditures had been

34. See *Broadband in America, supra*, Table 15.

increasing since 2004 as they captured an increasing share of new broadband subscribers. Therefore, we assume that broadband's share of these companies' total wireline capital expenditures rose by four percentage points per year from 2003 to 2009. CITI estimates that 50 percent of total wireless capital expenditures in 2008 were directed to broadband, increasing to 60 percent in 2009. This surge reflects the recent acceleration in wireless broadband. Therefore, we assume that only 40 percent of wireless capital spending was directed towards broadband for each year from 2005 to 2007. Because little wireless broadband existed in 2003 to 2004, we assume that 20 percent and 30 percent of capital spending was directed towards broadband in 2003 and 2004, respectively. For satellite broadband, we assume that all investments were applied to broadband access. Table 5 below summarizes our estimates.

TABLE 5: ESTIMATED BROADBAND SHARE OF TOTAL CARRIER CAPITAL EXPENDITURES

Broadband Type	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Cable	30%	30%	30%	30%	30%	30%	30%
Wireline	28%	32%	36%	40%	44%	48%	52%
Wireless	20%	30%	40%	40%	40%	50%	60%
Satellite	100%	100%	100%	100%	100%	100%	100%

Source: *Broadband in America*, *supra,* Table 15.

Applying these percentages to the 2003-2007 Census (ACES) figures in Table 4, and combining these with the CITI estimates for 2008-2009, yields the results shown in Table 6. These calculations suggest that investment in broadband was between $20 and $30 billion annually from 2003 to 2009, much higher than our 2003 projections of $7 to $8 billion annually.[35] One plausible explanation for this underestimate is that the FCC materially

35. *Ubiquitous Broadband Adoption*, *supra,* Table 8 at 21.

altered the regulatory climate *after* we made these projections. In particular, the FCC issued a forbearance order that committed the agency to a policy of not requiring the unbundling of fiber-based facilities of network operators. Such forbearance likely increased the expected returns of fiber-based investments and thereby strengthened the BSPs' investment incentives, as the upside potential associated with those investments could not be truncated with a mandatory sharing requirement.[36]

TABLE 6: ESTIMATED CARRIER BROADBAND CAPITAL EXPENDITURES, 2003-2009
($ BILLIONS)

Year	Current Estimates of Broadband Capex	Projections from Our 2003 Study	Difference Between Estimates
2003	$18.2	$5.1	$13.1
2004	$21.2	$6.7	$14.5
2005	$27.9	$7.1	$20.8
2006	$32.0	$7.4	$24.6
2007	$33.3	$8.6	$24.7
2008	$31.0	$10.0	$21.0
2009	$30.0	$8.2	$21.8
Average	***$27.7***	***$7.6***	***$20.1***

In addition to the change in regulatory policy, there are two other likely explanations why the investment projections in our 2003 study were lower than the estimated investments in Table 6. *First*, we only considered capital expenditures for residential broadband in our 2003 study. The more recent estimates of capital expenditures in Table 6, however, do not differentiate between residential and business

36. *See* Jerry Hausman, *The Effect of Sunk Costs in Telecommunications Regulation*, in THE NEW INVESTMENT THEORY OF REAL OPTIONS AND ITS IMPLICATION FOR TELECOMMUNICATIONS ECONOMICS 191-204 (James Alleman & Eli Noam, eds. Kluwer Academic Publishers 1999).

broadband spending. *Second*, we did not consider the possibility of wireless access technologies providing first-generation broadband speeds. Thus, we did not include investment in wireless technologies in our 2003 study, but instead focused only on cable modem and DSL as first-generation technologies. Accordingly, our 2003 study was conservative.

Included in the capital expenditures shown in Table 6 are substantial investments in more advanced technologies such as Fiber-to-the-Home (FTTH), Fiber-to-the-Node (FTTN), Docsis 3.0, and Wireless 4G. Table 7 lists some of the major reported investments in second-generation technologies. Although the list is far from comprehensive, we can glean that investment in these technologies from 2004 through 2009 was at least $45 billion, suggesting that our previous work also underestimated the rate of technological innovation.

TABLE 7: INVESTMENTS IN SECOND GENERATION BROADBAND TECHNOLOGY

Company	Investment Years	Total Investment ($ millions)
4G- WIMAX		
OpenRange	2009	$75
Clearwire	2008-2009	$2,094
DOCSIS 3.0		
Comcast	2009	$500
Knology	2008-2009	$103
Mediacom		$15
RCN	1H 2009	$17
Cablevision	2008-Q1 2009	$300
FTTH & FTTN		
Cincinnati Bell	2008	$15
Verizon	2004-2010	$23,000
AT&T	2006-2008	$5,000
SATELLITE		
Dish Network (Wild Blue)	2008	$230
ViaSat	2008-2009	$117
WIRELESS 3G/4G LTE		
AT&T	2008-2009	$12,227
Cox	2009	$500
MetroPCS	2008-2009	$1,258
Total		***$44,193***

Note: This list is far from comprehensive; Open Range is scheduled to spend $374 million between 2009 and 2014, we assume they spend the same amount each year for deployment.
Sources: *Broadband in America, supra*, Table 15; Saul Hansell, Cablevision Goes for U.S. Broadband Speed Record, N.Y. TIMES, Apr. 28, 2009; Jeff Baumgartner, Knology Goes on the Offensive, CABLE DIGITAL NEWS, Feb. 2009, *available at* http://www.lightreading.com/document.asp?doc_id=172415&site=cdn (accessed on Dec., 23, 2009); Saul Hansen, Verizon's FiOS, A Smart Bet or a Big Mistake, N.Y. TIMES, August 18, 2008.

D. Actual versus predicted benefits of household computing capacity

As we predicted in 2003, the increased demand for residential broadband has created additional demand for computers and networked-home appliances.[37] According to the National Telecommunications and Information Administration (NTIA), the percentage of households with a computer increased from 56.5 percent in September 2001 to 61.8 percent in October 2003.[38] Nielsen reported that as of November 2008, nearly 80 percent of households have a computer, and among those 90 percent have Internet access.[39]

Additionally, more and more households have invested in multiple computers. According to the NPD Group, 33 percent of homes with computers had more than two computers in 2009.[40] According to the NTIA, the increased usage of DSL and cable modem connections has stimulated an increase in home wireless local-access networks, as users share broadband connections across multiple computers.[41] Further, non-computer devices have been developed to connect to the Internet. Gaming consoles,[42] iPods,[43] electronic

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37. *Ubiquitous Broadband Adoption*, *supra*, at 7-9.

38. Kathleen B. Cooper, *A Nation Online: Entering the Broadband Age*, National Telecommunications and Information Administration (2004), at Figure 1.

39. Summary of An Overview of Home Internet Access in the U.S., Nielsen (2008), at 1, *available at* http://blog.nielsen.com/nielsenwire/wp-content/uploads/2009/03/overview-of-home-internet-access-in-the-us-jan-6.pdf (accessed on Dec. 23, 2009).

40. This 33 percent share of computer homes owning more than two computers is a weighted average of multi-computer Apple and Windows PC households reported by NPD. NPD reports that 12 percent of computer owning households own Apples, that 66 percent of households with Apples own three or more computers, and that 29 percent of Windows PC households own two or more computers. See Press Release, NPD Group, Inc., *Apple and Windows Computers Living Together Under One Roof, According to New NPD Report* (Oct. 5, 2009), *available at* http://www.npd.com/press/releases/press_091005.html.

41. National Telecommunications and Information Administration, *Networked Nation: Broadband in America 2007*, (2008), at 20 ("The increasing penetration of broadband DSL and cable, discussed above, has stimulated a commensurate climb in Wi-Fi adoption as people deploy home WLANs to share broadband connections among several computers.").

42. PlayStation3 System Features, *available at* http://www.us.playstation.com/ps3/features (accessed on Dec. 23, 2009); Xbox 360, *available at* http://www.xbox.com/en-US/hardware/compare101.htm (accessed on Dec. 23, 2009); Wii Connect Online, *available at* http://us.wii.com/hardware.jsp (accessed on Dec. 23, 2009).

43. iPod Touch, *available at* http://www.apple.com/ipodtouch/features/ (accessed on Dec. 23, 2009).

book readers,[44] and even refrigerators[45] have network and Internet capabilities.

In our 2003 report, we projected personal expenditures on computers, peripheral equipment and software to be $83 billion by 2009.[46] The basis of this projection was that the growth in consumer spending on computers would return to its average annual growth rate from 1991 to 1995 of 14.2 percent rather than the 9.9 percent average annual growth achieved between 1995 and 2000.[47] However, as Table 2 shows, actual personal consumption expenditures (PCE) on computers, peripheral equipment, and software increased from $42 billion in 2002 to $64.5 billion in 2008,[48] or about 7 percent per year.[49]

Our projections of PCE on computers and related equipment were fairly accurate for 2003 to 2007; we slightly under-estimated expenditures for 2003 and 2004, and slightly over-estimated them for 2005 and 2006. Our estimates for 2007 to 2008, however, were $10 to $20 billion too high for a number of reasons. The most compelling reason is obviously the recent recession. Total personal consumption expenditures, for example, only grew by three percent from 2007 to 2008, after having increased by between 4.9 and 6.4 percent each year from 2003 to 2007.[50] The rate of growth in consumer expenditures in computers, peripherals, and slowed even more—from between 5 percent and 10.7 percent

44. Amazon Kindle, *available at* http://www.amazon.com/Wireless-Reading-Display-International-Generation/dp/B0015T963C/ref=sa_menu_kdp2i3 (accessed on Dec. 23, 2009).

45. LG Internet Refrigerator, *available at* http://us.lge.com/www/product/refrigerator_demo.html (accessed on Dec. 23, 2009).

46. In 2001, nominal personal consumption spending fell to $32.9 billion. Using a 14.2 percent annual growth rate, we calculate our year over year estimates for consumption on , peripheral equipment, and software. *See Ubiquitous Broadband Adoption, supra,* at 8-9.

47. *Id.*

48. Bureau of Economic Analysis (BEA), Table 2.4.5U Personal Consumption Expenditures by Type of Product, data downloaded at http://www.bea.gov/national/nipaweb/nipa_underlying/Index.asp (accessed on Dec. 23, 2009).

49. *Id.*

50. *Id.*

each year from 2003 to 2007, to only 1.5 percent from 2007 to 2008. As the economic climate continues to improve, we can expect consumer expenditures on household computing equipment to begin growing more rapidly once again.

E. Actual versus predicted job creation

Residential broadband capital expenditures have a multiplicative effect on the economy if the economy is at less than full employment.[51] The multiplier specific to the telecommunications equipment manufacturers translates the effect of telecommunications capital spending on U.S. employment and on gross domestic product (GDP).[52] Based on the forecasted capital expenditures by broadband providers, and using Bureau of Economic Analysis (BEA) multipliers, we predicted in our 2003 study that residential broadband investment could create an average of 61,000 jobs from investment in cable and DSL, and 140,000 new jobs a year from all investment in both first- and second-generation technologies from 2003 through 2021.[53] Assessing this prediction with precision is difficult

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51. The multiplier is a standard principle in the macroeconomics literature. *See, e.g.,* RUDIGER DORNBUSCH & STANLEY FISCHER, MACROECONOMICS 66 (McGraw Hill 6th ed. 1994). Richard Kahn first introduced the multiplier concept as an "employment multiplier." *See* Richard F. Kahn, *The Relation of Home Investment To Employment,* 41 ECON. J. 173, 173-98 (1931). John Maynard Keynes expanded upon this concept by introducing the "investment multiplier," which is the multiplier used in my analysis. *See* JOHN MAYNARD KEYES, A GENERAL THEORY OF EMPLOYMENT, INTEREST, AND MONEY 115 (Harcourt Brace & Co. 1964) (1936).

52. The multiplicative effect occurs because higher expenditures on telecommunications equipment—equivalent to higher demand for the products of equipment manufacturers—cause equipment manufacturers to hire more employees to meet the increased demand. The equipment manufacturers' incomes increase as well due to the increased expenditures, which, according to the consumption function, will increase their consumption as well. The increased consumption of equipment manufacturers will in turn increase the income and employment of their suppliers. The income and employment of those suppliers will then increase, and so on. An employment multiplier of 20 for telephone apparatus manufacturing would indicate that 20 jobs would be created nationally for every $1 million invested in that sector. The timeframe over which these benefits are accrued is debatable. The BEA suggests that one year is the appropriate time horizon for the multipliers to achieve their full effect. Other economists, however, have estimated that it may take as long as two years.

53. *Ubiquitous Broadband Adoption*, *supra*, at 14 and 20. We predicted that 61,000 new jobs would be created from investments in existing technologies at the time. However, since growth in more advanced technologies almost always comes from current generation customers, capital expenditures in more

ex post because there are no data that relate changes in employment to the impact of particular capital expenditures. The multiplier analysis measures both direct and indirect effects of a particular investment. Although one could potentially determine the number of employees hired by equipment manufacturers as a direct result of increased demand, it would be nearly impossible to measure the indirect effect of those employees' consumption on other industries without the use of the multipliers. Because it is difficult to empirically capture the inter-industry relations of the economy, it is hard to assess the accuracy of our predictions with any precision. The next-best test of our result is a comparison of the two major inputs in our analysis: (1) investment in broadband and (2) the multipliers.

As explained above, we underestimated the investment in broadband that occurred over the past decade. It is straightforward to compare the multiplier we used in our previous analysis and the multipliers that are used by the federal government's statistical agencies today. Indeed, the Bureau of Economic Analysis has reduced its estimates of these telecom equipment multipliers since we performed our 2003 analysis.

In our 2003 study, we used RIMS II multipliers provided in 2002. The multipliers were based on the 1997 national Benchmark Input-Output Table for the Nation and 1999 regional data. Our 2003 study used the mean of the employment multiplier for telephone and telegraph equipment (17.2278) and the employment multiplier for communication equipment (18.9885), for an average multiplier of 18.1082.[54] The latest BEA multipliers are

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advanced technologies will necessarily reduce investment in first generation technologies. Hence the net effect of investment equals the incremental effect of the more advanced technologies less the displacement of some of the effect of current generation investment it replaces.

54. U.S. DEPARTMENT OF COMMERCE, BUREAU OF ECONOMIC ANALYSIS, Regional Input-Output Modeling System (RIMS II), Table 1.4 (2002). Multipliers are based on the 1997 Benchmark Input-Output Table for the Nation and 1999 regional data. We use an average of the multipliers for telephone and telegraph apparatus (I-O code

based on the 1997 Benchmark Input-Output Table for the Nation and 2006 regional data. Due to changes in the industry classifications used by the BEA, we use the latest multipliers for telephone apparatus manufacturing (11.7592), broadcast and wireless communications equipment (13.7828), fiber-optic cable manufacturing (14.4065), and construction (26.6692) because those sectors would be the targets for capital spending by broadband providers.[55] Using these multipliers, Eisenach, Singer and West (2009) estimate separate multipliers for different types of broadband spending by applying weights to each of the

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56.0300, or SIC 3661) and communications equipment (I-O code 56.0500, or SIC 3663 & 3669) for capital expenditures on DSL and cable broadband because these two multipliers match the products purchased by telephone service and cable operators through their increased capital expenditures more closely than any other multiplier category. According to the 1987 SIC Manual, industry 3661 consists of "[e]stablishments primarily engaged in manufacturing wire telephone and telegraph equipment. Included are establishments manufacturing modems and other telephone and telegraph communications interface equipment." Industry 3663, or "Radio and Television Broadcasting and Communications Equipment," consists of "[e]stablishments primarily engaged in manufacturing radio and television broadcasting and communications equipment. Important products of this industry are closed-circuit and cable television equipment; studio equipment; light communications equipment; transmitters, transceivers and receivers (except household and automotive); cellular radio telephones; communication antennas; receivers; RF power amplifiers; and fixed and mobile radio systems." *See* U.S. DEPT. OF LABOR, OCCUPATIONAL SAFETY & HEALTH ADMINISTRATION, STANDARD INDUSTRIAL CLASSIFICATION MANUAL (1987), *available at* http://www.osha.gov/oshstats/sicser.html.

55. U.S. DEPARTMENT OF COMMERCE, BUREAU OF ECONOMIC ANALYSIS, Regional Input-Output Modeling System (RIMS II), Table 1.5 (2008). Multipliers are based on the 1997 Benchmark Input-Output Table for the Nation and 2006 regional data. These industries approximately match the expenditures made to deploy and connect broadband more closely than any other multiplier category. According to the 1997 NAICS definition, industry 334210 (Telephone apparatus manufacturing) consists of "[e]stablishments primarily engaged in manufacturing wire telephone and data communications equipment. These products may be standalone or board-level components of a larger system. Examples of products made by these establishments are central office switching equipment, cordless telephones (except cellular), PBX equipment, telephones, telephone answering machines, and data communications equipment, such as bridges, routers, and gateways." Industry 335921 (Fiber optic cable manufacturing) consists of "[e]stablishments primarily engaged in manufacturing insulated fiber-optic cable from purchased fiber-optic strand." Industry 230000 (Construction) includes, among other types of construction establishments, "[e]stablishments primarily responsible for the entire construction (i.e., new work, reconstruction, or repairs) of electric power and communication transmission lines and towers, radio and television transmitting/receiving towers, cable laying, and cable television lines; (2) establishments identified as power and communication transmission line construction management firms; and (3) establishments identified as special trade contractors engaged in activities primarily related to power and communication transmission line construction." Industry 334220 (Broadcast and wireless communications equipment) includes "establishments primarily engaged in manufacturing radio and television broadcast and wireless communications equipment. Examples of products made by these establishments are: transmitting and receiving antennas, cable television equipment, GPS equipment, pagers, cellular phones, mobile communications equipment, and radio and television studio and broadcasting equipment." *See* U.S. CENSUS BUREAU, 1997 NAICS AND 1987 SIC CORRESPONDENCE TABLES, *available at* http://www.census.gov/epcd/www/naicstab.htm.

industry multipliers based on the allocation of broadband capital spending to each industry.[56] They estimate the weighted average employment multipliers for FTTH (19.7437), cable broadband (14.7412), DSL (14.7412), and wireless broadband (14.6618).[57] We use the mean of their estimated FTTH and DSL multipliers for wireline broadband investments, their estimated cable multiplier for cable broadband investment, and their wireless multiplier for the investments in wireless broadband. For satellite broadband, we use the multiplier for the broadcast and wireless communications equipment industry.[58] Applying the more recent multipliers to our updated estimates of capital expenditures, we estimate that an average of 434,000 jobs were created per year from 2003 to 2009, whereas we had estimated an average of 140,000 jobs per year would be created over the same time period in our 2003 study. [59]

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56. Jeffrey A. Eisenach, Hal J. Singer, & Jeffrey D. West, *Economic Effects of Tax Incentives for Broadband Infrastructure Deployment*, Fiber-to-the-Home Council (2008) at 8.

57. *Id*. Table 2 at 8. FTTH weights are 30 percent for telephone apparatus manufacturing, 20 percent for fiber optic cable manufacturing, and 50 percent for construction; Cable weights are 80 percent and 20 percent for construction; DSL weights are 80 percent for telephone apparatus manufacturing and 20 percent for construction; Wireless weights are 93 percent broadcast and wireless communications equipment and 7 percent construction.

58. According to the definition of the NAICS industry corresponding to this multiplier, the industry 334220 (Broadcast and wireless communications equipment) includes "Satellite antennas manufacturing" and "Satellite communications equipment manufacturing", and "Space satellites, communications, manufacturing". See U.S. Census Bureau, 2007 NAICS Definition, *available at* http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007.

59. A recent study by Jed Kolko found that broadband did not provide for local economic development and employment growth. Kelko focuses on employment rates in areas with increased broadband usage, under the premise that broadband providers target areas where they expect higher economic growth. Our study focuses on the *nationwide* employment impact of broadband investment. Consider that when a provider invests in laying fiber in Fort Worth, Texas that fiber is purchased from a firm in New York. In order to fully capture employment benefits from the Fort Worth investment, one must consider the employment created from physically laying the fiber in Texas and from producing the fiber in New York. Employment would increase in both Fort Worth *and* New York. Kelko does not capture this effect in his analysis; we attempt to quantify it in the current study. For the Kelko study, *see* Jed Kelko*, Does Broadband Boost Local Economic Development*, Public Policy Institute of California, Jan. 2010, *available at* http://www.ppic.org/main/publication.asp?i=866.

TABLE 8: THE MULTIPLIER EFFECT OF BROADBAND CAPITAL EXPENDITURES ON U.S. EMPLOYMENT

YEAR	CURRENT ESTIMATES OF JOBS CREATED	2003 FORECAST OF JOBS CREATED	DIFFERENCE BETWEEN ESTIMATES
2003	282,347	93,228	189,119
2004	328,758	120,974	207,784
2005	431,295	128,652	302,644
2006	499,869	133,760	366,109
2007	526,390	155,289	371,101
2008	495,231	180,857	314,373
2009	474,857	149,108	325,749
Average	***434,107***	***137,410***	***296,697***

Source: Jeffrey A. Eisenach, Hal J. Singer, & Jeffrey D. West, Economic Effects of Tax Incentives for Broadband Infrastructure Deployment, Fiber-to-the-Home Council (2008) at 8; *Ubiquitous Broadband Adoption, supra*, at 14, 20.

As Table 8 shows, we likely underestimated the increase in employment that resulted from broadband investment. However, it is impossible to know with certainty the accuracy of our projections. Finally, it bears mentioning that some studies have attempted to link *local* employment levels to *local* broadband deployment. In our opinion, this analysis cannot possibly capture the full job effects from broadband investment because (1) the equipment purchased by a BSP is often produced in another location, and (2) local jobs directly associated with the deployment does not capture indirect job effects that flow from the spending by vendors who received the initial investment.

F. Actual versus predicted economic output

The multiplier effect described above also applies to overall economic output or growth. In our 2003 study, we predicted that first-generation broadband investment would result in a $179.7 billion ($9.5 billion a year) increase in U.S. GDP between 2003 and

2021.[60] According to our estimates, investment in both first- and second-generation technologies together would result in a $414 billion increase in economic output from 2003 to 2021.[61] Again, it is difficult to validate these predictions *ex post*. The direct and indirect effects of broadband investment on U.S. output are nearly impossible to measure because of the inter-industry effects created by the investments. For the reasons described above, the best alternative is to compare the inputs to our analysis, investment and the multipliers. Based on these comparisons, we again appear to have slightly under-estimated the effect on economic output.

The previous analysis used the output multiplier for telephone and telegraph equipment (2.969) and the output multiplier for communication equipment (2.8984), for an average multiplier of 2.82. Again, due to changes in the in the industry classifications the BEA uses, we use the latest multipliers for telephone apparatus manufacturing (2.6424), broadcast and wireless communications equipment (2.8309), fiber-optic cable manufacturing (3.0284), and construction (3.4617). Using these same multipliers, Eisenach, Singer and West (2009) calculated weighted average output multipliers for FTTH (3.1293), cable broadband (2.8063), DSL (2.8063), and wireless broadband (2.8739).[62] Applying these more recent multipliers, and the multiplier for satellite discussed above, to our updated estimates of capital expenditures, we estimate that economic output increased by $561.4 billion from 2003 to 2009 due to broadband deployment, whereas we had

60. *Ubiquitous Broadband Adoption*, *supra*, Table 6 at 17.
61. *Id.* at 20.
62. *Id.*

estimated an increase of $150 billion in economic output over the same time period in our 2003 study.

TABLE 9: THE MULTIPLIER EFFECT OF BROADBAND CAPITAL EXPENDITURES ON U.S. GDP
($ BILLIONS)

YEAR	CURRENT ESTIMATES OF INCREASED GDP	2003 FORECAST OF INCREASED GDP	DIFFERENCE BETWEEN ESTIMATES
2003	$52.6	$14.5	$38.1
2004	$61.3	$18.8	$42.4
2005	$80.6	$20.0	$60.6
2006	$92.6	$20.8	$71.8
2007	$96.8	$24.2	$72.6
2008	$90.3	$28.2	$62.1
2009	$87.2	$23.2	$64.0
Total	***$561.4***	***$149.8***	***$58.8***

Source: Jeffrey A. Eisenach, Hal J. Singer, & Jeffrey D. West, Economic Effects of Tax Incentives for Broadband Infrastructure Deployment, Fiber-to-the-Home Council (2008) at 8; *Ubiquitous Broadband Adoption, supra*, at 14, 20.

As Table 9 shows, we likely underestimated the economic output that resulted from broadband investment. However, as with employment, it is impossible to know with certainty the accuracy of our projections.

G. Actual versus predicted increase in consumer welfare

Dutz, Orszag and Willig (2009) estimate that the net benefits to U.S. households from home broadband relative to no home Internet were on the order of $32 billion in 2008.[63] It bears noting that in our earlier studies we were not trying to estimate realized consumer welfare in some earlier period; instead, we were trying to estimate consumer welfare at some point in the future when broadband penetration is universally adopted

63. Dutz, Orszag & Willig, *supra*, at 36.

using two different methodologies. *First*, we assumed a linear demand curve, with an elasticity of -1 to -1.5 in 2001-2002 when residential broadband penetration was 11.7 percent.[64] Next, we shifted this demand curve out with constant slope to project surplus with residential penetration at 50 percent and 94 percent.[65] *Second*, we used the same elasticity assumptions and methods above for a log-linear demand curve with a choke price of $120 per month.[66] Table 10 below presents our previous projections. Comparing predicted to actual increases in consumer welfare owing to broadband deployment is also difficult. To make predictions about consumer surplus in our previous report, we had to make assumptions about the shape of the demand curve and the elasticity of demand, for which we had limited empirical estimates. It is important to note that the Crandall-Jackson 2001 study estimated the welfare benefits for broadband for a time when penetration increases to 94 percent of households—a date well into the future. As we approach that level, consumer surplus rises because more households use broadband and the own price elasticity falls accordingly.

Short of having the actual consumer surplus for these scenarios, the next-best alternative is to assess the validity of our elasticity estimates. The latest available estimates of elasticities are from Dutz, Orzag and Willig, who report that the own price elasticities for broadband are -1.53, -1.17, -0.88, and -0.69 from 2005 through 2008.[67] These estimates suggest that the elasticity assumptions in our 2003 study were reasonable, further

64. *Ubiquitous Broadband Adoption, supra*, at 6.
65. *Id.*
66. *Id.*
67. Mark Dutz, Jonathan Orszag, & Robert Willig, *The Substantial Consumer Benefits Of Broadband Connectivity For U.S. Households*, Internet Innovation Alliance, July 2009, at 7.

suggesting that our projections from the 2003 study remain valid.

TABLE 10: CRANDALL, JACKSON, & SINGER ESTIMATED INCREASES IN CONSUMER SURPLUS UNDER DIFFERENT ASSUMPTIONS ABOUT THE SHAPE OF THE DEMAND CURVE (BILLIONS OF DOLLARS)

Elasticity	-1.0	-1.5
Linear Demand Curve		
Current Consumer Surplus	$9.5	$6.3
Predicted Consumer Surplus at 50% Penetration	$96.6	$64.4
Predicted Consumer Surplus at Ubiquitous Penetration	$351	$234.0
Demand Curve with Constant Elasticity and Choke Price of $120/mo.		
Current Consumer Surplus	$8.4	$6.5
Predicted Consumer Surplus at 50% Penetration	$37.7	$17.0
Predicted Consumer Surplus at Ubiquitous Penetration	$71.9	$32.3

Source: *Ubiquitous Broadband Adoption*, *supra*, Table 1 at 7.

H. The benefits of broadband applications

At the time of our 2003 report, we could only guess at the future applications for broadband. The general areas we believed to have the most potential benefits to consumers were telemedicine, telecommuting, shopping, entertainment, and telephone services.[68] These areas have all seen tremendous growth within the past decade, suggesting that our predictions are coming true.

Telemedicine and telecommuting can save consumers billions in transportation costs, particularly for rural communities and the elderly. Litan estimates that over the 25-year period from 2005-2030, telemedicine and telecommuting will provide elderly (ages 65 and over) Americans with benefits that could combine to generate as much as $927

68. *Ubiquitous Broadband Adoption*, *supra*, at 9.

billion in overall value.[69] Vo estimates that six and ten years subsequent to a nationwide implementation, annual cost savings from telemedicine would be $4.28 billion.[70] In 2009, UnitedHealth and Cisco joined together to launch a network linking patients and physicians across the country via broadband video.[71] Intel and GE entered into a similar arrangement, agreeing to invest $250 million over five years in a telemedicine project which targets the elderly.[72] These investments are in addition to a government stimulus investment of $6 billion in telemedicine.[73] The telemedicine market is expected to grow to $6 billion per year by 2012, up from $900 million in 2007.[74] The benefits of telecommuting include environmental benefits from decreased car use,[75] savings for employers in the form of reduced overhead and rents,[76] and increased productivity.[77] According to a 2006 estimate, 28 million Americans tele-commuted at least once a month, a number was predicted to rise to nearly 100 million by 2010.[78]

69. Robert E. Litan, *Great Expectations: Potential Economic Benefits to the Nation From Accelerated Broadband Deployment to Older Americans and Americans with Disabilities*, New Millennium Research Council (2005).

70. Alexander H. Vo, The Telehealth Promise: Better Health Care and Cost Savings for the 21st Century, AT&T Center for Telehealth Research and Policy, May 2008 at 3.

71. Vanessa Fuhrmans, UnitedHealth, Cisco Plan Medical Network, Wall Street Journal, July, 16, 2009.

72. *Id.*

73. *Id.*

74. *Id.*

75. Home Warriors, The Economist, Jul. 25, 2008 ("One study published earlier this year reckoned 33m Americans have jobs that could be done from home. If all of them started to telecommute instead of drive to work, oil imports would drop by over a quarter, and carbon emissions would fall by 67m metric tonnes a year.").

76. *Id*. ("A sure-fire way of saving money is to reduce the amount of office space and services—generally reckoned to be around $10,000 per employee annually. Telecommuting doesn't remove all those overheads at a stroke, but it can easily halve them.").

77. *Id*. ("There are productivity benefits, too. Telecommuters at American Express, for instance, are reckoned to generate over 40% more business than their office-bound colleagues. British Telecom's 9,000 teleworkers are apparently 30% more productive than their office counterparts.").

78. Christa Heibel, Benefits of Telecommuting, TMCNet, Dec. 10, 2007, *available at* http://smart-data-centers.tmcnet.com/topics/benefits/articles/16146-benefits-telecommuting.htm (accessed on Jan. 10, 2009).

E-Shopping provides benefits such as time savings, reduced costs to consumers from traveling to stores, and reduced costs to producers of holding inventory at multiple store locations. A 2008 Pew Internet report estimated that higher broadband deployment would drive up the number of online shoppers by nearly six percentage points.[79] The report observes that individuals with broadband at home are more likely to purchase something online by a large margin.[80] As broadband increases, presumably more consumers will be able to realize the benefits of online shopping.

Broadband has also provided consumers with increasing benefits in the realm of entertainment. Faster download speeds have allowed entertainment providers to offer consumers streaming videos and audio. It is now commonplace for television networks to provide their viewers with on-demand episodes of recently aired televisions shows.[81] ESPN along with individual sports leagues even allow viewers to stream live sporting events from their home computers or hand-held devices.[82] Broadband connections have also enabled consumers to download audio faster, or to simply stream live radio, podcasts, or music directly to their PC's or home audio systems. Similarly, gaming has benefited from increasing broadband connection speeds. Many games are now playable online, and include online communities where thousands of players can play on the same platform at once. These benefits have even begun to extend to mobile broadband devices.

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79. John Horrigan, Online Shopping, Pew Internet & American Life Project, Feb. 2008 at 12, *available at* http://www.pewinternet.org/~/media//Files/Reports/2008/PIP_Online%20Shopping.pdf.pdf (accessed on Jan. 10, 2009).

80. *Id.*

81. Fox, NBC, CBS, and ABS all offer this service on their websites.

82. See ESPN360, *available at* http://espn.go.com/broadband/espn360/ (accessed on Jan. 10, 2009); NHL Gamecenter, *available at* https://gamecenter.nhl.com/nhlgc/secure/registerform?intcmpid=nhl.com:gcl:topstripfl (accessed on Jan. 10, 2009).

Broadband voice technologies can reduce infrastructure costs, lower costs to consumers, allow multiple calls over one network (decreasing the need for multiple phone lines), provide location independence (there would be no such thing as a long distance call), and allow for integration with other internet services. A recent analyst report found that Voice over Internet Protocol (VoIP) customers paid $20 less per month than traditional circuit switched line customers for telephone service. That report also projected that VoIP subscribers would increase from 17 million in 2008 to 31.5 million in 2012.[83]

Educational institutions have used broadband to provide unprecedented services to both teachers and students. Providing broadband connection speeds and continuous network connections can facilitate distance-learning opportunities through teleconferencing. Such technology has potential benefits for rural communities that may lack access to top-flight education resources.[84] There are several examples of distance tutoring programs internationally.[85] Broadband provides other educational benefits as well. Ubiquitous broadband adoption amongst schools can facilitate communication between teachers and students across the country.[86] Further development of online resources such as E-Books, Google Scholar, and Social Science Research Network (SSRN)

83. Gran Seiffert, Cost-Saving ICT Solutions, Media Planet, *available at* http://mediaplanetreports.com/voip/2009/06/cost-saving-ict-solutions/ (accessed on Jan 10, 2010).

84. Working Party on Communication Infrastructures and Services Policy, Network Developments in Support of Innovation and User Needs, Organization for Economic Cooperation and Development Dec. 2009 at 5 (Broadband is having a significant impact on education and e-learning by improving access to digital learning resources; encouraging communication among schools, teachers and pupils; promoting professional education for teachers; and linking local, regional, and national databases for administrative purposes or supervision.") *available at* http://www.olis.oecd.org/olis/2009doc.nsf/LinkTo/NT0000889E/$FILE/JT03275973.PDF (accessed on Jan. 10, 2009) [hereinafter *OECD report*].

85. For example, see TutorVista, at http://www.tutorvista.com/ (accessed on Jan. 10, 2010).

86. *OECD report, supra, at 30.*

provide academic institutions with access to fast and reliable research.[87] Recent reports indicate that U.S. primary and secondary school broadband adoption is nearing 100 percent, suggesting that these benefits may be realized in the near future.[88]

The recent emergence of online social networking, with groups such as Facebook[89] and Twitter,[90] provides users with a forum to connect with friends, colleagues, and family. A recent Nielsen report indicated that 17 percent of all online time is spent on blogging or social networking.[91] Improved download speeds have allowed these groups to provide improved services. For instance, Facebook allows users to share photos and videos with other members of the network.[92] In addition to staying connected, social networking sites allow employers to reduce information costs of investigating a potential new hire.[93] Similarly, sites such as LinkedIn also reduce time and costs involved in searching for employment.

Data networks can serve as the basis for new smart electrical grids, with communication via broadband enabling consumers to get real time data on their

87. *Id.* at 33.
88. *Id.* at 34.
89. Facebook reports 350 million active users, with 2.5 billion photos uploaded to the site each month, 3.5 billion in other content (such as videos and web links), with 50 percent of active users logging on per day, see http://www.facebook.com/press/info.php?statistics (accessed on Jan. 10, 2009).
90. Twitter has seen a recent explosion in users, going from 2.4 million tweets a day in November 2009 to nearly 26 million a day tweets by October 2009, see Noam Cohen, "Refining the Twitter Explosion," New York Times. November 8, 2009.
91. Sarah Perez, "Social Networking Use Triples From Only a Year Ago," ReadWriteWeb.
92. Facebook used almost a petabyte of storage space to manage its users' 40 billion photographs, *see* Ashlee Vance, "Training to Climb an Everest of Digital Data," New York Times. October 12, 2009, *available at* http://www.nytimes.com/2009/10/12/technology/12data.html (accessed on Jan. 10, 2010).
93. Jenna Wortham, "More Employers Use Social Networks to Check Out Applicants," New York Times Bits [blog]. Aug. 20, 2009; Matt Warburton, *Cost per resume lower with LinkedIn job posts*, *available at* http://talent.linkedin.com/blog/index.php/2009/12/cost-per-resume-lower-with-linkedin-job-posts/ (accessed on Jan. 10, 2010).

consumption and on overall supply and demand.[94] Such a system could reduce unnecessary energy use, and give providers the necessary information to ration demand through flexible pricing and to ensure efficient supply. In transportation, broadband can help planners understand and model traffic flows in real time.[95] The information can be used to divert traffic patterns, or to inform drivers of faster routes. This information can help reduce congestions. Additionally, reducing travel times could increase productivity or provide utility for consumers.

Despite these impressive developments, broadband applications are still at a relatively primitive stage; therefore, the opportunities for innovative uses will proliferate as download speeds increase. As broadband investments continue and broadband adoption becomes ubiquitous, benefits to consumers and the economy will continue to increase.

I. The spillover effects of broadband in other industries

In our 2003 paper, we predicted that broadband adoption would cause consumers to spend more in upstream industries, leading to increased capital spending by these upstream industries, which would create jobs, and economic output.[96] The accuracy of this prediction is again difficult to measure as it is problematic to isolate the cause of investment in upstream industries. Several studies have attempted to quantify this effect,

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94. Working Party on Communication Infrastructures and Services Policy, Network Developments in Support of Innovation and User Needs, Organization for Economic Cooperation and Development Dec. 2009 at 5 (Broadband is having a significant impact on education and e-learning by improving access to digital learning resources; encouraging communication among schools, teachers and pupils; promoting professional education for teachers; and linking local, regional, and national databases for administrative purposes or supervision.") *available at* http://www.olis.oecd.org/olis/2009doc.nsf/LinkTo/NT0000889E/$FILE/JT03275973.PDF (accessed on Jan. 10, 2009).

95. *Id.*

96. *Ubiquitous Broadband Adoption*, *supra*, at 21-22.

and based on their conclusions, we are even more confident that broadband provides a host of benefits to other sectors in the economy.

Since our 2003 paper, the most relevant study on these spillover effects came from Crandall, Lehr, and Litan, who tested the proposition that broadband penetration, along with a host of other factors, including levels of taxation, unionization, education, wages, and geography, would have a demonstrable effect on employment and output, in aggregate, and by sector.[97] They conducted a regression analysis using state-level broadband penetration data for the lower 48 states from 2003-2005,[98] measuring broadband penetration by lines per 100 inhabitants. Their results showed that nonfarm private employment and employment in several industries was positively associated with broadband use. In particular, for every one percentage point increase in broadband penetration in a state, employment is projected to increase by 0.2 to 0.3 percent per year.[99] On a national level, their results imply an increase of approximately 300,000 jobs.[100] At the sector level, Crandall, Lehr, and Litan found that employment in several industries is positively related to broadband penetration, particularly in areas such as finance, education and healthcare.[101] Their results confirm that broadband plays a particularly important role in service-oriented sectors where employees are more likely to be reliant on the ability to access the internet from anywhere.[102]

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97. *Id* at 8.
98. Robert Crandall, William Lehr, and Robert Litan, *The Effects of Broadband Deployment on Output and Employment: A Cross-sectional Analysis of U.S. Data*, THE BROOKINGS INSTITUTION: ISSUES IN ECONOMIC POLICY NO. 6 (2007).
99. *Id* at 2.
100. *Id.*
101. *Id*.
102. *Id* at 12.

IV. The Future Effect of Investment in Broadband Technologies on the Economy

Our review of the recent trends surrounding the deployment of broadband provides us with information to forecast future investment. In this section, we set forth our forecasts for going-forward broadband investment and project the effect of this investment on the U.S. economy. We estimate that annual average investment spending in 2003-09 was:

- $4.3 billion in ***cable modem*** services, which corresponds to 63,400 jobs created.
- $11.7 billion in wireline broadband, including ***DSL and fiber***, which corresponds to 202,400 jobs created.
- $11.6 billion in ***3G wireless and satellite technologies***, which corresponds to 168,300 jobs created.

Again, our estimates of jobs created are relative to a world in which such investments did not take place. Looking forward to 2015, we predict that the average annual investment in new technologies will be:

- $12.5 billion in wireline broadband, including ***FTTH and FTTN***, which corresponds to 247,000 jobs created.
- $3.6 billion in cable broadband, including ***DOCSIS 3.0***, which corresponds to 52,000 jobs created.
- $14.3 billion in ***wireless and satellite technologies***, which corresponds to 205,000 jobs created.
- $300 million in ***satellite broadband***, which corresponds to over 4,000 jobs created.
- $30.4 billion in ***all broadband technologies***, which corresponds to over 509,000 jobs created.

These future investments will be extremely important in promoting growth and maintaining employment in the current economic climate.

A. Going-forward investment forecasts in broadband technology

A recent study by the Columbia Institute for Tele-Information (CITI) estimated that capital expenditures in the telecom industry in 2009 were $60 billion.[103] CITI predicts that capital investment will remain in the $50 to $60 billion range for the near term, as providers continue to upgrade services with FTTH and DOCSIS 3.0.[104] CITI further attempts to estimate capital expenditures on broadband alone, allocating a portion of total capital expenditures to broadband. Table 11 below replicates the investments projected by CITI for 2010 to 2015.

TABLE 11: TOTAL CAPEX AND BROADBAND CAPEX BY SECTOR (IN $ MILLIONS)

Type	2008	2009E	2010E	2011E	2012E	2013E	2014E	2015E
Wireline (DSL)								
Major Provider Capex	26,283	21,060	19,353	17,458	16,755	16,420	16,203	16,095
Total Capex	32,289	25,872	23,775	21,447	20,583	20,172	19,905	19,773
% Broadband	48%	52%	54%	58%	62%	62%	62%	62%
Wireline Broadband Capex	***15,499***	***13,454***	***12,839***	***12,439***	***12,762***	***12,506***	***12,341***	***12,259***
Cable								
Major Provider Capex	13,148	11,817	12,109	12,237	12,476	12,818	12,969	12,986
Total Capex	15,956	14,342	14,695	14,851	15,140	15,556	15,739	15,760
% Broadband	30.00%	30.00%	30.00%	*25.0%*	25.00%	*20.0%*	20.00%	20.00%
Cable Broadband	***4,787***	***4,302***	***4,408***	***3,713***	***3,785***	***3,111***	***3,148***	***3,152***
Wireless								
Major Provider Capex	19,520	18,597	17,990	17,449	17,251	17,140	17,070	17,036
Total Capex	20,700	19,721	19,077	18,504	18,294	18,176	18,102	18,066
% Broadband	50.00%	60.00%	64.00%	68.00%	73.00%	78.00%	81.00%	85.00%
Wireless Broadband	***10,350***	***11,833***	***12,210***	***12,583***	***13,354***	***14,177***	***14,663***	***15,356***
Other								
Satellite Broadband	200	200	200	300	400	400	200	300
WISP Broadband	199	219	241	265	292	321	353	388
Total Broadband Capex								
Total Capex	***69,344***	***60,354***	***57,989***	***55,367***	***54,709***	***54,624***	***54,300***	***54,287***
Total Broadband Capex	***31,035***	***30,008***	***29,898***	***29,300***	***30,593***	***30,516***	***30,705***	***31,455***

Source: *Broadband in America, supra*, Table 15.

It is important to note that these data combine investments in both business and residential broadband. Further, the table shows investment in both first- and second-

103. *Broadband in America, supra,* at 11.
104 . *Id.* at 11.

generation technology together. Presumably, most of this investment will be in second-generation technologies. It is clear, however, that a very large share of this capital spending will continue to occur in the wireless sector. In 2008 alone, $10.3 billion dollars in capital expenditures was expended on wireless networks, or 33 percent of all broadband-related capital expenditures, according to the CITI estimates. This number is projected to rise to $15.4 billion in 2015, accounting for approximately half of all broadband-related capital expenditures. Capital expenditures in both wireline and cable broadband services are projected by CITI to decline somewhat as those services complete their build-out. Of course, these forecasts assume that even faster technologies do not loom on the horizon. Satellite and WISP broadband are projected to receive modest but steady investments through 2015.

B. Effects of second-generation investment on economy

The projected increase in capital expenditures resulting from the deployment of second-generation broadband will be especially beneficial for telecommunications equipment manufacturers. These firms derive a large share of the benefits of new technology deployment in the form of increased demand for their products, which are used to build and maintain broadband networks. In addition to equipment manufacturing, other sectors of the economy will thrive because general economic activity is positively linked to telecommunications investment, just as the deployment of first-generation broadband created jobs and increased general economic output. We project an average of 510,000 jobs in the United States will be sustained from 2010 to 2015 as a result of broadband investments relative to a world without such investments. We also project that investment in broadband deployment will increase U.S. economic output by $542 billion from 2010 to

2015 relative to a world without such investments.

1. Increased jobs

As we discuss above, the effect of investment on employment is measured through the BEA's multiplier for industries most affected by that investment. To measure the impact of future investment in broadband deployment, we use the forecasts of broadband deployment shown in Table 9 and the multipliers discussed above from Eisenach, Singer and West (2009). We use their estimated FTTH multiplier for wireline broadband investments, their estimated cable multiplier for cable broadband investment, and their wireless multiplier for the investments in wireless broadband (including WISP). For satellite broadband, we use the multiplier for the broadcast and wireless communications equipment industry.[105] Table 12 summarizes the effects on employment from projected broadband deployment from 2010 to 2015.

105. According to the definition of the NAICS industry corresponding to this multiplier, the industry 334220 (Broadcast and wireless communications equipment) includes "Satellite antennas manufacturing" and "Satellite communications equipment manufacturing", and "Space satellites, communications, manufacturing". See U.S. Census Bureau, 2007 NAICS Definition, *available at* http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2007.

TABLE 12: MULTIPLIER EFFECT OF FORTHCOMING BROADBAND INVESTMENTS ON EMPLOYMENT, 2010-2015

Year	2010	2011	2012	2013	2014	2015	Avg.	Total
Broadband Capital Expenditures ($ Billions)								
Wireline	$12.8	$12.4	$12.8	$12.5	$12.3	$12.3	$12.5	$75.1
Cable	$4.4	$3.7	$3.8	$3.1	$3.1	$3.2	$3.6	$21.3
Satellite	$0.2	$0.3	$0.4	$0.4	$0.2	$0.3	$0.3	$1.8
Wireless/WISP	$12.5	$12.8	$13.6	$14.5	$15.0	$15.7	$14.0	$84.2
Total	$29.9	$29.3	$30.6	$30.5	$30.7	$31.5	**$30.4**	**$182.5**
Employment Multipliers								
Wireline	19.7437	19.7437	19.7437	19.7437	19.7437	19.7437		
Cable	14.7412	14.7412	14.7412	14.7412	14.7412	14.7412		
Satellite	13.7828	13.7828	13.7828	13.7828	13.7828	13.7828		
Wireless/WISP	14.6618	14.6618	14.6618	14.6618	14.6618	14.6618		
Jobs Created through Multiplier Effect								
Wireline	253,489	245,592	251,969	246,915	243,657	242,038	247,277	
Cable	64,979	54,734	55,795	45,860	46,405	46,464	52,373	
Satellite	2,757	4,135	5,513	5,513	2,757	4,135	4,135	
Wireless/WISP	182,554	188,375	200,075	212,567	220,162	230,835	205,761	
Total	503,779	492,836	513,353	510,854	512,980	523,472	**509,546**	

As Table 12 shows, second-generation broadband deployment will result in an average of more than a half-million U.S. jobs sustained from 2010 to 2015 relative to a world without such investments, assuming that the multiplier's effect is captured within one year. This assumption is realistic given the slack in the economy that has resulted in an unemployment rate of 10 percent in January 2010.[106]

2. Higher growth rates in economic output

The deployment of second-generation broadband technologies will stimulate the growth of the overall U.S. economy beyond what is captured in employment. To measure this economic growth, we use the GDP multipliers discussed above from Eisenach, Singer and West (2009). We use their FTTH multiplier for wireline broadband investments, their

106. Press Release, U.S. Dept. of Labor, Bureau of Labor Statistics, *The Employment Situation – December 2009* (Jan. 8, 2010) (on file with author).

cable multiplier for cable broadband investment, and their wireless multiplier for the investments in wireless broadband (including WISP). For satellite broadband we use the multiplier for the broadcast and wireless communications equipment industry. Table 13 summarizes the effects on GDP from projected second-generation broadband deployment from 2010 to 2015.

TABLE 13: MULTIPLIER EFFECT OF FORTHCOMING BROADBAND INVESTMENTS ON GDP, 2010-2015

Year	2010	2011	2012	2013	2014	2015	Avg.	Total
Broadband Capital Expenditures ($ Billions)								
Wireline	$12.8	$12.4	$12.8	$12.5	$12.3	$12.3	$12.5	$75.1
Cable	$4.4	$3.7	$3.8	$3.1	$3.1	$3.2	$3.6	$21.3
Satellite	$0.2	$0.3	$0.4	$0.4	$0.2	$0.3	$0.3	$1.8
Wireless/WISP	$12.5	$12.8	$13.6	$14.5	$15.0	$15.7	$14.0	$84.2
Total	$29.9	$29.3	$30.6	$30.5	$30.7	$31.5	**$30.4**	**$182.5**
GDP Multipliers								
Wireline	3.1293	3.1293	3.1293	3.1293	3.1293	3.1293		
Cable	2.8063	2.8063	2.8063	2.8063	2.8063	2.8063		
Satellite	2.8309	2.8309	2.8309	2.8309	2.8309	2.8309		
Wireless/WISP	2.8739	2.8739	2.8739	2.8739	2.8739	2.8739		
Increased GDP through Multiplier Effect								
Wireline	$40.2	$38.9	$39.9	$39.1	$38.6	$38.4	$39.2	$235.2
Cable	$12.4	$10.4	$10.6	$8.7	$8.8	$8.8	$10.0	$59.8
Satellite	$0.6	$0.8	$1.1	$1.1	$0.6	$0.8	$0.8	$5.1
Wireless/WISP	$35.8	$36.9	$39.2	$41.7	$43.2	$45.2	$40.3	$242.0
Total	$88.9	$87.1	$90.9	$90.7	$91.2	$93.3	**$90.3**	**$542.1**

Source: Capital expenditures from CITI estimates.

As Table 13 shows, the cumulative $182.5 billion in forecasted broadband deployment will sustain economic output worth $542.1 billion between 2010 and 2015, or an average of $90.3 billion per year, relative to a world without such investment.

3. Sensitivity to accelerated deployment schedule and expanded scope

The estimates of the economic impact of broadband flow from our baseline assumptions about broadband deployments discussed above. To test the sensitivity of our results, we estimate the economic effect of more expansive deployment than that currently projected by broadband providers. Additional investments would be required if any broadband provider decided to deploy next-generation broadband to areas beyond current projections. For example, one assumption built into the capital expenditure projections in Table 11 is that Verizon will increase its fiber footprint from 14.5 million homes in 2009 to a terminal point of 18 million homes in 2011 (equal to 70 percent of its total footprint, subsequent to Frontier transaction).[107] Given the appropriate economic conditions and regulatory incentives, Verizon could instead build out 90 percent of its footprint by 2015 (equal to 23 million homes)—an additional 5 million homes beyond current projections. In addition, AT&T is currently projected to deploy FTTN to 30 million homes by 2011 (equal to 45.6 percent of its 65.7 million local loops as of December 2006)[108] and none thereafter. Under a more ambitious deployment schedule, AT&T could build out 70 percent of its footprint by 2015 (equal to 46 million homes)—an additional 16 million homes beyond current projections.

Under these more ambitious deployment scenarios, the number of new homes passed by AT&T and Verizon's fiber from 2009 to 2015 would be 34.5 million rather than the projected increase of 13.5 million. Conservatively assuming capital expenditures on wireline broadband under the more ambitious deployment scenario increases as much (in percentage terms) as the number of new homes passed, wireline broadband capital expenditures from 2010 to 2015 would be $192.0 billion (versus $75.1 billion in the

107. *Broadband in America*, *supra,* at 27.

108. Federal Communications Commission, Industry Analysis and Technology Division, Wireline Competition Bureau, *Trends in Telephone Service*, Table 7.3 at 7-5 (Aug. 2008).

baseline scenario), and *total* broadband capital expenditures would be $299.4 billion (versus $182.5 billion in the baseline scenario).[109]

Under the more expansive deployment scenario, the effect of broadband providers' investments between 2010 and 2015 would be a cumulative increase of $907.9 billion in GDP and an average of 894,000 jobs per year, peaking at 905,000 additional jobs in 2012.

According to the U.S. Department of Labor, seasonally-adjusted employment in the communications *services* sector decreased from 1,032,600 in December 2007 to 965,900 in December 2009—a total of 66,700 lost jobs.[110] Seasonally-adjusted employment in the communications *equipment* sector decreased from 128,000 in December 2007 to 124,400 in December 2009—a total of 3,600 lost jobs.[111] Seasonally-adjusted employment in the utility system construction industry decreased from 459,200 in December 2007 to 406,100 in November 2009—a total of 53,100 lost jobs.[112] Across these sectors of the communications and construction industries, more than 123,000 jobs were lost over the two-year period between the beginning of the recession in December 2007 and the end of 2009. We estimate that the capital expenditures by broadband providers would more than restore those job losses by the end of 2010 under our more expansive deployment scenario when compared to our baseline scenario, *if no new regulatory changes undermine the incentives of broadband service providers (see policy section below).*

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109. Extending FTTH or FTTN to less densely populated areas would likely require greater investment per home passed. We have assumed that the cost per home passed for Verizon or AT&T to extend their footprints would not increase. Therefore, our estimates the resulting capital expenditures are conservative.

110. U.S. Department of Labor, Bureau of Labor Statistics, Employment, Hours, and Earnings from the Current Employment Statistics Survey, *available at* http://www.bls.gov/ces/cesprog.htm (last visited Jan. 8, 2010).

111. *Id.*

112. *Id.*

C. Spillover Effects of Second-Generation Broadband Investment in Other Sectors of the Economy

As a result of the investment in second-generation broadband and the ensuing adoption resulting from that investment, consumers will increase spending in a variety of upstream industries. This increase in spending will in turn result in increased capital spending by these upstream industries. This increased industry investment will have a multiplicative effect on the economy that supplements the effect resulting from broadband provider capital spending discussed above. Although the impact on these upstream industries cannot be foreseen with precision, we attempt to provide a rough estimate of the potential effects. Table 14 lists a few of these industries in which capital expenditures are likely to increase as faster internet connections become available and broadband subscriptions grow. For purposes of this analysis, we assume that the capital expenditures by firms in these industries will increase by five percent from their 2008 levels as a result of the increased broadband adoption.

TABLE 14: THE ESTIMATED EFFECT OF A FIVE PERCENT INCREASE IN CAPITAL SPENDING RESULTING FROM SECOND-GENERATION BROADBAND DEPLOYMENT ON GDP AND TOTAL EMPLOYMENT

Industry	2008 Investment ($Bil.)	5% Increase	Empl. Multiplier	GDP Multiplier	Effect from Multiplier: Empl. (# of Jobs)	Effect from Multiplier: GDP ($Bil.)
Educational Services	27.0	1.35	32.4969	3.1583	43,871	4.3
Health care and social assistance						
Ambulatory health care services	52.5	2.625	25.5798	3.0613	67,147	8.0
Hospitals	69.0	3.45	28.7792	3.2685	99,288	11.3
Nursing & residential care facilities	4.3	0.215	28.7792	3.2685	6,188	0.7
Social assistance	2.6	0.13	40.6758	3.1981	5,288	0.4
Accommodation (such as hotels)	17.2	0.86	25.6163	2.7286	22,030	2.3
Information						
Publishing industries	10.1	0.505	17.6843	2.7865	8,931	1.4
Motion picture & sound recording	1.6	0.08	21.0532	3.2860	1,684	0.3
Amusements & recreation services	11.5	0.575	35.1679	2.9364	20,222	1.7
Manufacturing						
Computer and electronic products	28.6	1.43	14.1355	2.8355	20,214	4.1
Miscellaneous manufacturing	7.6	0.38	16.9433	3.0115	6,438	1.1
Retail trade	69.0	3.45	27.9428	2.9018	96,403	10.0
Wholesale trade	60.1	3.005	18.0960	2.7150	54,378	8.2
Total:	361.1	18.1			**452,081**	**53.8**

Sources: BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Standard Fixed Assets Table 3.7ES, *available at* http://www.bea.gov/national/FA2004/SelectTable.asp; BUREAU OF ECONOMIC ANALYSIS, U.S. DEPARTMENT OF COMMERCE, Regional Input-Output Modeling System (RIMS II), Table 2.5 (2008).

As Table 14 shows, the increased capital spending in these industries could result in an increase of up to 452,000 jobs.

V. POLICY IMPLICATIONS

Our job and output estimates from the prior sections quantify what is at stake in the current “broadband debate.” In contemplating a national broadband plan, regulators must be careful not to undermine the incentive of BSPs to carry though on these investments, given their importance in driving greater consumer value and growth in jobs and national output. In this section we critique some of the proposals that are appear to be under consideration at the Federal Communications Commission, then we offer some constructive alternatives that are more consistent with the objective of economic welfare maximization.

A. Defining the Right Objective

Many discussions of broadband policy begin with the notion that increasing broadband penetration should be the singular goal for policymakers. If maximizing short-run penetration were the only objective—that is, if broadband were declared a universal service—then the best policy might be for the government to provide the service directly (paid by the tax system) or to subsidize broadband for all consumers.

But broadband penetration is not a satisfactory measure of *consumer welfare*. Consumer welfare is a function of both immediate metrics such as price and penetration of current legacy broadband networks, and longer-run variables such as innovation in more advanced networks. Economics teaches that maximizing consumer welfare—and not output or penetration—should be the objective of policymakers. Once the proper objective comes into focus, it becomes clear that certain policies currently under consideration are not socially optimal.

B. Some of the Policies Being Considered by the Commission Would Reduce Consumer Welfare

One policy that has been championed by the Berkman Center at Harvard University is "open access" to BSPs' networks. In a 2009 study commissioned by the Federal Communications Commission, the Berkman Center compared broadband penetration across countries and credited "open access" as a major determinant of high subscriber penetration. Although it is possible as a matter of theory for "open access" to decrease prices and increase penetration of first-generation broadband services—the empirical evidence suggests no correlation between unbundling and broadband penetration[113]—"open access" could also reduce the incentives for broadband providers to invest in more advanced networks,[114] which could reduce overall consumer welfare in the long run. Economists refer to these longer-term effects as "dynamic effects." After receiving critical comments on that study, Blair Levin, a high-ranking officer at the Commission, said "… what's going on in other countries really isn't germane for where we go from here. … As to (line sharing rules), the courts threw that out and we're not that terribly interested(?) in moving toward things that will just freeze capital investment and have long, drawn-out court battles. … That doesn't strike me as that productive."[115]

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113. *See, e.g.,* Glenn Boyle, Bronwyn Howell and Wei Zhang, Catching up in Broadband: Does Local Loop Unbundling Really Lead to Material Increases in OECD Broadband Uptake? New Zealand Institute for the Study of Competition and Regulation Working Paper (July 2008); Jerry A. Hausman & J. Gregory Sidak, *Did Mandatory Unbundling Achieve its Purpose? Empirical Evidence from Five Countries*. 1(1) JOURNAL OF COMPETITION LAW AND ECONOMICS 226 (2005); Debra Aron & David Burnstein, Broadband Adoption in the United States: An Empirical Analysis, Working Paper, LECG Ltd. (March 2003); Johannes Bauer, Jung Kim, & Steven Wildman, Broadband Uptake in OECD Countries: Policy Lessons and Unexplained Patterns, Paper prepared for the European Regional Conference of the International Telecommunications Society (August 2003); Mario Denni & Harald Gruber, The Diffusion of Broadband Telecommunications: The Role Of Competition, Paper presented at the International Communications Society Conference (2005); Walter Distaso, Paolo Lupi, & Fabio Manenti, Platform Competition And Broadband Uptake: Theory And Empirical Evidence From The European Union, Paper presented at the joint PURC - University of Florida and LBS 2005 telecommunications conference (April 2005); Inmaculada Cava-Ferreruela & Antonio Alabau-Munoz, *Broadband Policy Assessment: A Cross-National Empirical Analysis*, TELECOMMUNICATIONS POLICY 30 (2006); Leonard Waverman, Meloria Meschi, Benoit Reillier, & Kalyan Dasgupta, Access Regulation and Infrastructure Investment in the Telecommunications Sector: An Empirical Investigation, Working Paper, LECG Ltd. (Sept. 2007).

114. *See* Scott Wallsten & Stephanie Hausladen, *Net Neutrality, Unbundling, and Their Effects On International Investment In Next-Generation Networks*, REVIEW OF NETWORK ECONOMICS (2009) (showing that the relationship between unbundling and next-generation network penetration is negative and statistically significant for both incumbents and entrants); Michal Grajek & Lars-Henrick Roller, *Regulation and Investment in Network Industries: Evidence from European Telecoms* EMST Working Paper 09-004 (showing that access regulation negatively affects both total industry and individual carrier investment, and that regulators respond endogenously to incumbent infrastructure investments by providing easier access to entrants); Robert W. Crandall, Allan T. Ingraham & Hal J. Singer, *Do Unbundling Policies Discourage CLEC Facilities-Based Investment?*, 4 BERKELEY ELECTRONIC JOURNAL: TOPICS IN ECONOMIC ANALYSIS AND POLICY (2004) (showing that mandatory unbundling encourages a CLEC to delay facilities-based investment by altering its relative net present value of investment between time periods).

115. Amy Schatz, *FCC Eyes Average Internet Speeds for Rural Areas*, WALL STREET JOURNAL, Dec. 21, 2009, *available at* http://blogs.wsj.com/digits/2009/12/21/fcc-eyes-average-internet-speeds-for-rural-areas.

As Mr. Levin properly recognized, it is impossible to offer informed policy prescriptions without considering both the potential benefits (increased immediate output) and costs (decreased investment) of "open access" regulations. Indeed, dynamic efficiency is typically much more important to consumers than static efficiency in sectors with rapidly-changing technology. Undermining the incentive to invest in a new product may lead to missing or delayed markets, where but-for gains in producer and consumer surplus are *eliminated in their entirety*, while static inefficiency may lead only to relatively small deadweight losses in consumer and producer surplus.[116]

The Commission is also considering ways of expanding broadband access to rural areas of the country. For connection speeds of 3 Mbps, it estimates the costs of a universal-service program to be $30 billion.[117] Although much of that investment would have to come from the private sector, the Commission is considering changes to a $7 billion annual federal-phone-subsidy program to fund new broadband Internet lines in rural areas. One proposal would subject recipients of the grants to certain line-of-business restrictions. In particular, a grant seeker would agree to serve as a wholesale-only provider—that is, after constructing its network, the BSP would agree to resell its lines to third-party retailers, who in turn would interface with rural customers.

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116. *See*, *e.g.*, Austan Goolsbee, *The Value of Broadband and the Deadweight Loss of Taxing New Technology*, 5(1) CONTRIBUTIONS TO ECONOMIC ANALYSIS AND POLICY, 1-29, at 4 (2006) (finding that the dynamic efficiency losses from a hypothetical tax applied to broadband Internet in the U.S. exceed the allocative efficiency losses by a factor of two or three); Robert Solow, *Technical Change and the Aggregate Production Function*, 9(3) REVIEW OF ECONOMICS AND STATISTICS, 312-320 (1957) (concluding that approximately 87 percent of the source of economic growth in the United States in the first half of the 20century could be explained by technical change, rather than by increases in capital and labor); Paul Romer, *New Goods, Old Theory, and the Welfare Costs of Trade Restrictions*, 43(1) JOURNAL OF DEVELOPMENT ECONOMICS, 5-38. (1994) (finding that the dynamic efficiency losses from an import tariff could be as much as 20 times allocative efficiency losses).

117. Schatz, *supra*.

Such a policy would also be inconsistent with the notion of welfare maximization because it would discourage many BSPs from participating in the grant program (increasing the cost of the subsidy and reducing the amount of investment), and because it would prevent grant recipients from exploiting economies of scope in the wholesale and retail provision of broadband service. Economics teaches that even a monopolist passes on cost savings to end users; it would therefore be inefficient to deny these providers certain cost savings.

Another policy that is getting serious consideration by the Commission is called "net neutrality." In its simplest form, net neutrality would bar a BSP from contracting with a content provider for the provision of enhanced or priority service at a positive price. Again, such a rule is not consistent with the proper objective of maximizing welfare. To begin, the provision of broadband Internet service is what is known in economics as a "two-sided" market because BSPs interact with two distinct groups of consumers, content providers and end-users.[118] Content providers' demand for broadband service is driven by their desire to reach end-users, and end-users' demand for broadband service is driven by the content on the Internet. Consequently, BSPs must consider this interdependence when setting their prices. Economic research on two-sided markets has demonstrated that socially optimal pricing (the set of prices that maximizes the value of the network) requires the platform to charge lower prices to the side of the market with the more elastic demand

118. Jean-Charles Rochet & Jean Tirole, *Platform Competition in Two-Sided Markets*, 1 J. EURO. ECON. ASSOC. 990 (2003).

(that is, the greater sensitivity to increases in prices).[119] Moreover, these prices can vary substantially depending on the nature of the service and the consumer's demand for it. A blanket rule forbidding BSPs from charging content providers for enhanced service would necessarily prevent BSPs from using incremental revenues garnered from the content side of the market to lower the prices for end-users.[120] Thus, net neutrality would perversely attenuate the value of the Internet to both content providers and end-users in aggregate.

Net neutrality regulation is also likely to reduce innovation in both the development of network infrastructure and the provision of Internet-based content. Proponents of net neutrality regulation have tried to co-opt the innovation argument by contending that innovation from small content-providers at the fringe of the network will be discouraged if these entities are forced to contract for enhanced service. Taken to its logical conclusion, however, this argument implies that Internet access should be provided free of charge to all content providers to maximize innovation on the fringe of the network without consideration of the effects of such a policy on innovation in the core of the network. But this argument assumes that the network infrastructure of the internet is simply a commodity product that can be supplied at zero cost by a number of fungible BSPs. It ignores the fact that both the initial establishment of the network and its ongoing

119. Wilko Bolt & Alexander F. Tieman, *Skewed Pricing in Two-Sided Markets: An IO Approach*, Netherlands Central Bank Research Department Working Paper 013 (2005) at 1 ("In two-sided markets, one widely observes skewed pricing strategies, in which the price mark-up is much higher on one side of the market than the other. Using a simple model of two-sided markets, we show that, under constant elasticity of demand, skewed pricing is indeed profit maximizing. The most elastic side of the market is used to generate maximum demand by providing it with platform services at the lowest possible price. Through the positive network externality, full participation of the high-elasticity, low-price side of the market increases market participation of the other side. As this side is less price elastic, the platform is able to extract high prices. Our skewed pricing result also carries over when analyzing the socially optimal prices.").

120. Although it is true that content providers already make contributions to revenue via charges for Internet access and (in some cases) transit, some content providers would be willing to make even greater contributions to revenue if offered higher QoS.

management require significant investment. Moreover, forbidding content providers from contracting for superior service is likely to deter innovation from content providers whose content or applications would benefit from, and may only be possible with, enhanced quality-of-service or prioritization.

C. A Better Way Forward

In this section, we briefly offer some alternative policies that are more consistent with the objective of maximizing welfare. Unlike the policies under consideration at the Commission, our preferred approach would not undermine the incentives of BSPs to invest in second-generation technologies. Without such investment, consumer value will be sacrificed and jobs in the telecommunications industry will be lost.

Subsidize complements. A critical ingredient to broadband adoption in areas that are already served by BSPs is the hardware used by subscribers. Although regulators have largely focused their attention on the broadband service itself, it might be more effective to focus some resources on increasing the demand for computers and other devices that connect to the Internet. Economics teaches that a decrease in the price of a complement for good *A* increases the demand for good *A*. Indeed, Telmex recognized this problem in Mexico, and began a computer-subsidy program intended to stimulate the demand for its broadband service. (Because Telmex is more likely to win a new broadband account than a given BSP in the more competitive U.S. broadband market, BSPs cannot be counted on to subsidize hardware to the same degree.) To make this idea concrete, low-income consumers could receive subsidies, either directly or as a tax credit for buying a computer. Given the very low introductory prices for broadband service in most parts of the country, it is hard to accept that, for all but the poorest households, the monthly price for broadband service is the major impediment to adoption. For many, a $300 computer could be a bigger obstacle than a $15 monthly commitment for an introductory broadband plan.

Tax incentives: BSPs cannot be expected to upgrade their networks in areas of the country in which the private costs of such upgrades will exceed the private benefits. Economists refer to a situation in which the social benefits associated with a certain activity exceed the private benefits as a "positive externality." In the presence of positive externalities, it is possible that the private sector will undersupply a service relative to the "socially optimal" level—that is, although the social benefits exceed the private costs, the private benefits are less than the private costs. If the policy goal is near-ubiquitous deployment of next-generation technologies, then policymakers could provide tax incentives to BSPs to upgrade the marginally unprofitable areas. One choice for such an incentive is through the tax code—for example, in the form of an accelerated capital expensing allowance.

Reverse auctions: Rather than offering a fixed grant to suppliers who are willing to embrace unproven business plans (such as wholesale-only or a duty to support all online applications), regulators could conduct reverse auctions to deploy broadband networks in under-served or rural areas. In a reverse auction, the price of the subsidy begins high and falls until the last bidder is willing to serve the area at the auction price. In most cases, the winning bidder will be the one with the lowest cost structure, which ensures an efficient allocation. A reverse auction obviates the need of the regulator to choose one technology over another; for example, wireless 3G might be the lowest-cost solution for rural areas, but not for urban areas. And one wireless 3G provider might have lower costs than another. Relative to grants that provide a fixed amount of money, reverse auction should reduce the overall amount of the subsidy.

VI. Conclusion

Broadband deployment has enhanced consumer welfare and spurred jobs and economic output. Many of our original predictions of broadband investment and its effects on jobs and national output were conservative because we could not envision the rapid development of new technologies and the myriad applications made possible by rapidly advancing broadband technology. Looking forward, we observe that BSPs are set to invest significant sums to wire the country with next-generation access technologies. Given the amount of investment that continues to be deployed in this sector and the precarious current state of the U.S. economy, and given the linkage between that investment and jobs/output, regulators must avoid taking any steps that might undermine the industry's incentives to invest.

Biographies

Robert W. Crandall

Robert W. Crandall is a Non-Resident Senior Fellow in Economic Studies at the Brookings Institution in Washington, D.C., a position that he has held since 1978. His areas of expertise are antitrust, telecommunications, the automobile industry, competitiveness, deregulation, environmental policy, industrial organization, industrial policy, mergers, regulation, and the steel industry.

Previously, Dr. Crandall was an Assistant Professor and Associate Professor of Economics at the Massachusetts Institute of Technology between 1966 and 1974. He has also taught at George Washington University. He has twice served in the federal government. He was Acting Director, Deputy Director, and Assistant Director of the Council on Wage and Price Stability in the Executive Office of the President. In 1974-75, he was an adviser to Commissioner Glen O. Robinson of the FCC. Dr. Crandall has been a consultant on regulatory and antitrust matters to the Antitrust Division of the U.S. Department of Justice, to the Federal Trade Commission, to the Canadian Competition Bureau, and to more than twenty companies in the telecommunications, cable television, broadcasting, newspaper publishing, automobile, and steel industries. He has also been a consultant to the Environmental Protection Agency and the U.S. Department of the Treasury.

Dr. Crandall has written widely on telecommunications policy, the economics of broadcasting, and the economics of cable television. He is the author or co-author of seven books on communications policy published by the Brookings Institution since 1989. He is the author of *Competition and Chaos: U.S. Telecommunications since the 1996 Act* (Brookings Institution 2005). With James H. Alleman, he is the author of *Broadband: Should We Regulate High-Speed Internet Access* (Brookings Institution 2002). With Leonard Waverman, he is co-author of *Who Pays for Universal Service? When Telephone Subsidies Become Transparent* (Brookings Institution 2000) and *Talk Is Cheap: The Promise of Regulatory Reform in North American Telecommunications* (Brookings Institution 1996). With Harold Furchtgott-Roth, he is co-author of *Cable TV: Regulation or Competition?* (Brookings Institution 1996). He is also the author of *After the Breakup: U.S. Telecommunications in a More Competitive Era* (Brookings Institution 1991). With Kenneth Flamm, he is co-author of *Changing the Rules: Technological Change, International Competition, and Regulation in Communications* (Brookings Institution 1989). In addition, he has published four other books on regulation and industrial organization with the Brookings Institution. With Pietro S. Nivola, he is co-author of *The Extra Mile: Rethinking Energy Policy for Automotive Transportation* (Brookings Institution 1995). He is the author of *Manufacturing on the Move* (Brookings Institution 1993). With Donald F. Barnett, he is co-author of *Up From Ashes: The U.S. Minimill Steel Industry* (Brookings Institution 1986). He is also co-author with Howard K. Gruenspecht, Theodore E. Keeler, and Lester B. Lave of *Regulating the Automobile* (Brookings Institution 1986). Dr. Crandall's work has been cited on numerous occasions by the federal judiciary and the Federal Communications Commission (FCC).

He received an A.B. (1962) from the University of Cincinnati and a Ph.D. in Economics (1968) from Northwestern University.

Hal J. Singer

Hal J. Singer is a Managing Director at Navigant Economics. He is also an adjunct professor at the

McDonough School of Business at Georgetown University. His areas of economic expertise are antitrust, finance, and regulation. He is the co-author of the book *Broadband in Europe: How Brussels Can Wire the Information Society* (Kluwer/Springer Press 2005). He has also published book chapters in *Access Pricing: Theory, Practice and Empirical Evidence* (Justus Haucap and Ralf Dewenter eds., Elsevier Press 2005); *Handbook of Research in Trans-Atlantic Antitrust* (Philip Marsden, ed., Edward Elgar Publishing 2006); and *Longevity Trading and Life Settlements* (Vishaal Bhuyan ed., John Wiley & Sons 2008). He has published scholarly articles in dozens of economics and legal journals.

Dr. Singer's scholarship has been widely cited by regulators and by courts. In the Solicitor General's September 2008 amicus brief submitted to the Supreme Court in Pacific Bell Telephone Company v. linkLine Communications, Inc, the first citation of authority was to an article on price squeezes that Dr. Singer co-authored with Dr. Robert Crandall of the Brookings Institution. Dr. Singer also served as a testifying expert on impact and damages in several antitrust litigation matters, including Natchitoches Parish Hosp. Serv. Dist. v. Tyco Int'l, Ltd. et al. (D. Mass.), Meijer, Inc. & Meijer Distribution, Inc. et al. v. Abbott Laboratories, (N.D. Ca.), and Southeast Missouri Hospital et al. v. C.R. Bard, Inc. (E.D. Mo.). In each case, the class certification order favorably cited Dr. Singer's testimony. In an October 2008 order, the Federal Communications Commission cited Dr. Singer's work on behalf of the National Football League (NFL) in support of the agency's decision to refer the NFL's complaint against Comcast to an administrative law judge. In June 2008, the arbitrator in TCR Sports Broadcasting Holdings v. Time Warner extensively relied on Dr. Singer's analysis to determine the fair-market value of an out-of-region telecast of the Baltimore Orioles and Washington Nationals.

Dr. Singer is a frequent speaker and editorial writer; his columns have appeared in several leading newspapers, including the *Wall Street Journal*, the *Washington Post*, and Canada's *National Post*. Dr. Singer earned M.A. and Ph.D. degrees in economics from the Johns Hopkins University and a B.S. *magna cum laude* in economics from Tulane University.